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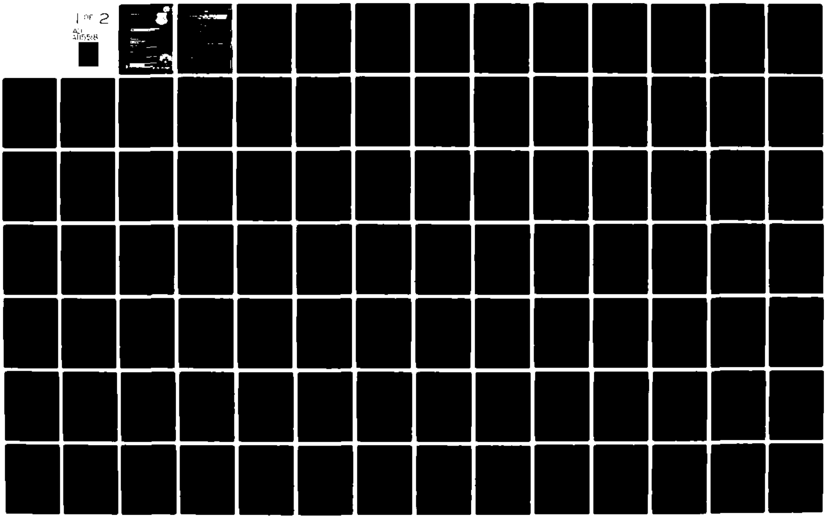

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The large number of factors commonly encountered in simulation and live field test programs dictates that a large (and costly) experimental program be run if the classical full factorial experimental design is employed. Through the use of a screening process involving a sequential design, efficient economical pilot studies can be conducted, leading to a reduction in the number of factors and the size of the experimental space. Fractional factorial designs are used in the pilot studies. The experimental data

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provide guidance to the experimenter in terms of removing nonsignificant factors and thus reducing the size of the experimental space.

This report documents the initial design, development, and use of an interactive computer program to aid in the development of fractional factorial experimental designs. Fractional factorial experiments are a special class of experimental procedures that allow the user to perform a smaller number of experiments than would be required in the usual experimental procedures and which maximize information return while minimizing the number of observations (tests) required. The overall experimental design philosophy is described and a brief introduction into the theory of experimental design is presented. The Appendix describes how the computer program was constructed and how it should be used. A specific example related to the MISVAL (Missile Launch Envelope Technology Program) is included.

PREFACE

This program was developed under Air Force Aerospace Medical Research Laboratory Contract No. F33615-79-C-0505. The AFAMRL contract monitor and project engineer was Dr. Robert G. Mills. The authors are indebted to Mr. Philip V. Kulwicki, Visual Display Systems Branch (AFAMRL), for his support and guidance in applying the experimental design interactive computer program to the Missile Launch Envelope simulation research program. The authors also acknowledge the assistance of Dr. David Marshall now at the University of Alabama, Huntsville, Alabama.

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GLOSSARY

Alias	Effect that cannot be distinguished from another effect.
Alpha	Probability of rejecting a hypothesis when it is true.
Beta	Probability of accepting a hypothesis when it is false.
Confounding	An experimental arrangement in which certain effects cannot be distinguished from others.
Correlation Coefficient (PEARSON R)	The square root of the proportion of total variation accounted for by linear regression.
Correlation Index R	The square root of the proportion of total variation accounted for by the regression equation of the degree being fitted to the data.
Defining Contrast	Selection of effects to be confounded.
Degrees of Freedom	One less than the number of values required to compute the sum of squares.
Effect	Change in response caused by a change in the level of a factor.
Errors	Type I: Rejecting a hypothesis when true. Type II: Accepting a hypothesis when false.

Experiment Model	Hypothesized equation to describe the response as a function of the treatment.
Experimental Unit	A single set of factor values applied to the experimental subject and for which a response value is to be measured.
Factorial Experiment	An experiment in which all levels of each factor in the experiment are combined with all levels of every other factor.
Fractional Replication	An experimental design in which only a fraction of a complete factorial is run.
F-Test	A statistical test to check for equal means between two populations.
Interaction	An interaction between two factors means that a change in response between levels of one factor is not the same for all levels of the other factor.
Mean Square Error	Sum of squares of the error divided by the number of degrees of freedom for the error term.
Regression	Linear - Response = A*X1+B*X2+C*X3+...+Z*XN; Quadratic - Response = A*X1+B*X2+...+ C*X1*X2+D*X1*X3+ ...+E*X1**2+F*X2**2+
Rejection Criteria	Test structure used to reject the null hypothesis.

R-Squared	Small r-Squared--refer to Correlation Coefficient Big R-Squared--refer to Correlation Index.
Statistical Hypothesis	HO: An assumption about a population being sampled.
Test of Hypothesis	A rule by which a hypothesis is accepted or rejected.

INTRODUCTION

The Air Force Aerospace Medical Research Laboratory (AFAMRL) is engaged in the use of human operators to perform critical systems evaluation. The size and complexity of the various systems preclude the detailed analysis that would enable AMRL to examine each aspect of every system. Large numbers of factors (independent variables) are commonly encountered in real-world simulation or field problems. Complete full factorial experimental designs for problems involving large numbers of factors (20 factors are not uncommon) are very costly in time, manpower, and other test resources.

The use of fractional factorial designs permits the experimenter to employ sequential experimental design techniques. See Cochran and Cox (1957) and other references for a complete discussion of fractional factorial experimental designs. In this procedure, the various factors are examined and a potentially significant subset is defined. By using the proper aliasing of effects, a small fractional (or full) factorial experiment can be conducted. If additional effects/interactions are identified as being highly significant or if additional interactions are required to be examined, a larger fractional factorial design can be constructed by removing some of the aliasing requirements. This process of designing an experiment, data analysis, and design refinement is the basis of sequential experimental design.

Examples of multivariable design problems can be found in many Air Force and other R&D programs, e.g. Aume, Mills et al., 1977. AMRL has been studying these experimental design problems for a number of years, including the studies performed by Simon (1973), Mills (1973),and Williges (1973, 1979) relating to human factors experimentation. This report represents an effort to implement some of the design strategies previously proposed.

Human factors experimentation is an especially critical area of research because the experimenter must consider the factors in the system being studied and the variations introduced by the presence of a human subject. To overcome these perturbations, the experimental procedure must be run many times with several different subjects to remove effects caused by the subjects and to identify variations caused by the parameters being studied. Since this procedure requires a large number of experimental trials (e.g., observations, tests, etc.), it may not be feasible to conduct a study because of cost and time. One way to overcome this problem is to employ a set of experimental designs called fractional factorial experimental designs. Fractional factorial experiments are a special class of reduced data collection designs that allow the user to perform a smaller number of observations than would be required in the usual experimental procedures.

This effort provides the reader with an automated tool to design fractional factorial experiments. A tape of the Automated Interactive Sequential Experimental Design program source listing in Fortran 4.5 can be obtained from AFAMRL/HEF, ATTN: Dr. Robert G. Mills, W-PAFB, OH 45433. For the purposes of this report, the authors assume that the reader possesses at least a conceptual knowledge of symmetrical experimental design procedures including fractional factorials. This assumption also holds true for the user of the initial version of the computer program which is being described. However, a long range objective of this effort is to eventually develop the program to the extent that, via the interactive mode, the program's user need have only a minimum knowledge of experimental design procedures. The primary intent is to develop the computer program such that it can be readily applied by the engineering, etc. community that is involved with performing simulator and live testing of systems. It should also be noted that although the computer program presented herein is designed to assist the sequential experimental design process (i.e., a series of experiments), it can also be used to create a "one-shot" experimental design.

This report provides background on sequential design and the mathematical formulations implemented in the computer program. A discussion of how an experiment should be conducted is contained in PHILOSOPHY OF EXPERIMENTAL DESIGN. The class of experimental designs known as fractional factorial designs is described along with the terminology involved, the concept of aliasing, the evaluation of designs, and means of defining basic experimental blocks. Brief commentaries on data collections, redesign, and irregular fractional factorial experiments are provided in DATA COLLECTION, REDEFINING DESIGN, AND IRREGULAR FRACTIONAL FACTORIAL EXPERIMENTS. PREDEFINED DESIGNS contains listings of predefined fractional factorial designs including optimal aliasing selection to reduce aliasing of main and first-order effects. A selected bibliography of books and reports that present more detailed information on these topics is given in REFERENCES.

The Appendix provides a detailed step-by-step description of the computer program usage. A specific example related to an Air Force technology development program is included. Usage of the computer program assumes some knowledge on the part of the user.

THE PHILOSOPHY OF EXPERIMENTAL DESIGN

The basis for an experimental design philosophy consists of six steps:

1. Problem recognition and initial study
2. Preliminary model definition
3. Data collection plan development
4. Data collection
5. Data analysis
6. Analysis of results and model reformulation.

In the first step, the experimenter recognizes the existence of a problem. He begins a preliminary study to identify the problem bounds and its associated parameters. This initial study provides a crude model of the system. In the second step, the experimenter examines this preliminary model and identifies those features that severely affect the performance of the system. He designs a data collection plan that enables him to test the previously hypothesized significant features. Without an adequate data collection plan, the experimenter may arrive at erroneous conclusions.

Once the data collection plan (called the experimental design) is complete, the experimenter "collects" the data. After the data are collected, data analysis is performed. Data analysis consists of the standard analysis methods, e.g., regression analysis and analysis of variance methods if any of the experimental factors are qualitative. This analysis identifies those factors that account for most of the system variation. According to Pareto's Principle, 80 percent of the variation in a system can be attributed to 20 percent of the factors.

After the data analysis is performed, the experimenter redesigns or refines his system model based on the results of the previous experimentation. This cycle of redesign, data collection, and analysis continues until the experimenter is satisfied with the accuracy of his results. At this point, he draws conclusions about the system based upon the experimentation.

THE NEED FOR DESIGNED EXPERIMENTS

An experiment is conducted to provide information. An experimenter needs information to identify problem areas, to identify important factors, and to quantify responses. He obtains this information by collecting data. After problem definition is complete, the first step in an experiment is to define questions that need to be answered. Once the questions are identified, an experiment can be designed to aid in answering those questions. The key issue is that an experimenter must design his experiment before any data are collected.

The designer of an experiment must consider the statistical accuracy and the cost of the experiment. Statistical accuracy involves the proper selection of the response to be measured, determination of the number of factors that influence the response, the selection of the subset of these factors to be studied in the experiment being planned, the number of times the basic experiment should be repeated, and the form of the analysis to be conducted.

The cost of an experiment includes expense incurred by running a single experimental condition (observation), analyzing the data, failing to meet a deadline, and most importantly, perhaps drawing incorrect conclusions from the experiment. Although cost as a factor is not often discussed in the literature, it is at least as important as considerations of statistical accuracy. In an attempt to minimize the cost of an experiment, the designer usually attempts to choose the simplest experimental design possible, and to use the smallest sample size consistent with satisfactory results. Fortunately, most simple experimental designs are both statistically efficient and economical, so that the designer's efforts to obtain statistical accuracy usually result in economy.

EXPERIMENTAL MODEL

The experiments being studied in a factorial experiment are called fixed effect models. The term fixed effect is related to the predefined levels that the various factors may assume. Consider two factors, A and B, which are being studied where there are N_A levels for treatment A and N_B levels for treatment B. The response in a two-factor experiment may be described by the model:

$$X_{ij} = \mu + \alpha_i + \beta_j + \alpha\beta_{ij} + \varepsilon_{ij}$$

$$i = 1, 2, \ldots, N_A$$

$$j = 1, 2, \ldots, N_B$$

where

μ = overall mean effect

α_i = true effect of the ith level of factor A

β_j = true effect of the jth level of factor B

$(\alpha\beta)_{ij}$ = effect of the interaction between α_i and β_j

ε_{ij} = experimental error

A similar model for three factors may be written as:

$$X_{ijk} = \mu + \alpha_i + \beta_j + \gamma_k + (\alpha\beta)_{ij} + (\alpha\gamma)_{ik} + (\beta\gamma)_{jk} + (\alpha\beta\gamma)_{ijk} + \varepsilon_{ijk}$$

The assumptions in a full factorial experiment allow for the examination of each main effect and all interactions. A fractional factorial experiment assumes that the high-order interactions are insignificant. For example, in the three-factor model, if the assumption is made that the interactions $(\alpha\gamma)$, $(\beta\gamma)$, and $(\alpha\beta\gamma)$ are insignificant, the model becomes:

$$X_{ijk} = \mu + \alpha_i + \beta_j + \gamma_k + (\alpha\beta)_{ij} + \varepsilon_{ijk}$$

This permits fewer experimental observations to determine the relative significance of the remaining terms in the model. The effects considered to be insignificant are included in the model error term.

This experimental model can be evaluated using the standard analysis of variance (ANOVA) techniques or a regression analysis may be run to determine regression coefficients.

NOMENCLATURE--NOTATION AND TERMINOLOGY

The previous section showed that responses could be modeled as equations involving true effects of each factor at the level involved, the effects of the interactions among factors, the overall mean effect, and the true test (experimental) error. The techniques for manipulating response data from individual experimental trials to arrive at estimates of the values for each of the terms in the mathematical model involve consideration of response values for various combinations of factors and levels. Two standard means of notation are used to represent these response values. These are illustrated in the following example.

Consider an experiment involving three factors with each factor having two possible levels. If the factors are represented by a, b, and c, and the levels by 0 and 1, the possible trials and notations used to represent the responses are shown in Table 1.

Table 1. Full Factorial, Three-Factor, Two-Level Experiment

EXPERIMENTAL TRIAL (FACTOR AND LEVEL)	EFFECT OR INTERACTION	NOTATION
$a_0b_0c_0$	I	000
$a_0b_0c_1$	C	001
$a_0b_1c_0$	B	010
$a_0b_1c_1$	BC	011
$a_1b_0c_0$	A	100
$a_1b_0c_1$	AC	101
$a_1b_1c_0$	AB	110
$a_1b_1c_1$	ABC	111

Main effects are represented by those trials whose notation has a nonzero value in only one column of the notation. Two-factor, or first-order interactions, are represented by those trials whose notation has a nonzero value in two columns. Higher-order interactions are represented by those trials whose notation has a nonzero value in more than two columns. In this example, main effects are A, B, and C. First-order interactions are AB, AC, and BC. The only higher-order interaction is ABC.

It is apparent from Table 1 that the notation consists simply of the subscripts representing the levels of the factors in sequential order (thus, trial $a_0b_1c_1$ has a response notation of 011). The effect or interaction response is represented by the sequence of the factors raised to the power of the level involved (thus, trial $a_0b_1c_1$ results in the interaction response $A^0B^1C^1$ = BC).

In a similar manner, effects and notations can be defined for the three-level case. Consider an experiment involving three factors with each factor having three possible levels. If the factors are represented by a, b, and c, and the levels by 0, 1, and 2, the possible trials and notations used to represent the responses are shown in Table 2. Note that main effects are C, C^2, B, B^2, A, and A^2 because the notation for these trials has a nonzero value in only one column of the notation.

FRACTIONAL FACTORIAL EXPERIMENTS

A full factorial experimental design involves an experiment in which every level of each factor is combined with every level of every other factor. If an experiment has N factors and each factor may assume one of P levels, there is a total of P^N different combinations.

Table 3 is an example of an experiment with three factors at two levels. This example is taken from an AMRL study of the MISVAL program. The term "MISVAL" designates the Missile Launch Envelope Technology Development Program being conducted by the Air Force Wright Aeronautical Laboratories at Wright-Patterson Air Force Base, Ohio. The definitions of factors and levels used in the examples are not considered necessary in order to convey the intent of the examples. Also, note that the factors are qualitative and thus, would have to be appropriately scaled or used in a different design in an actual experimental program.

Table 2. Full Factorial, Three-Factor, Three-Level Experiment

EXPERIMENTAL TRIAL (FACTOR AND LEVEL)	EFFECT OR INTERACTION	NOTATION
$a_0b_0c_0$	I	000
$a_0b_0c_1$	C	001
$a_0b_0c_2$	C^2	002
$a_0b_1c_0$	B	010
$a_0b_1c_1$	BC	011
$a_0b_1c_2$	BC^2	012
$a_0b_2c_0$	B^2	020
$a_0b_2c_1$	B^2C	021
$a_0b_2c_2$	B^2C^2	022
$a_1b_0c_0$	A	100
$a_1b_0c_1$	AC	101
$a_1b_0c_2$	AC^2	102
$a_1b_1c_0$	AB	110
$a_1b_1c_1$	ABC	111
$a_1b_1c_2$	ABC^2	112
$a_1b_2c_0$	AB^2	120
$a_1b_2c_1$	AB^2C	121
$a_1b_2c_2$	AB^2C^2	122
$a_2b_0c_0$	A^2	200
$a_2b_0c_1$	A^2C	201
$a_2b_0c_2$	A^2C^2	202
$a_2b_1c_0$	A^2B	210
$a_2b_1c_1$	A^2BC	211
$a_2b_1c_2$	A^2BC^2	212
$a_2b_2c_0$	A^2B^2	220
$a_2b_2c_1$	A^2B^2C	221
$a_2b_2c_2$	$A^2B^2C^2$	222

TABLE 3. MISVAL Example

LABEL	FACTOR	LOW LEVEL (0)	HIGH LEVEL (1)
A	MLE CONCEPT	FAAC CONCEPT	GD CONCEPT
B	PILOT FUNCTION	FUNCTION 1	FUNCTION 2
C	MISSILE TYPE	AIM-7F	AIM-9F

The $2^3 = 8$ combinations of these factors, which would comprise a full factorial experiment for the MISVAL program, are given in Table 4.

TABLE 4. Full Factorial Experiment

EXPERIMENTAL UNIT	LABEL	NOTATION	MLE CONCEPT	PILOT FUNCTION	MISSILE TYPE
1	I	000	FAAC	1	AIM-7F
2	C	001	FAAC	1	AIM-9F
3	B	010	FAAC	2	AIM-7F
4	BC	011	FAAC	2	AIM-9F
5	A	100	GD	1	AIM-7F
6	AC	101	GD	1	AIM-9F
7	AB	110	GD	2	AIM-7F
8	ABC	111	GD	2	AIM-9F

Table 5 shows the number of observations required in a full factorial experiment for experiments with 2 to 10 factors at 2 or 3 levels. Note that the number of observations required rises drastically as the number of factors and /or levels increases.

A full factorial experimental design provides an estimate of every possible effect, i.e., one is able to estimate those effects caused by all combinations of factors. In many experiments, interactions among factors may be insignificant. Interactions involving two factors are called first-order interactions, and interactions among three factors are called second-order interactions.

In many human factors experiments, the assumption that first, second, and higher-order interactions are insignificant is often reasonable (Simon, 1973).

Table 5. Full Factorial Experiment Size.

N NUMBER OF FACTORS	P = 2 LEVELS PER FACTORS	P = 3 LEVELS PER FACTORS
2	4	9
3	8	27
4	16	81
5	32	243
6	64	729
7	128	2187
8	256	6561
9	512	19683
10	1024	59649

The total number of effects and interactions is given by $P^N - 1$. The number of main effects is given by $(P - 1)N$. The number of first-order interactions is given by:

$$\frac{(P - 1)^2}{2} N(N - 1)$$

Thus, the number of higher-order interactions is given by

$$P^N - 1 - (P - 1)N - \frac{(P - 1)^2}{2} N(N - 1)$$

Table 6 shows the number of main, first-order, and higher-order effects for a variety of factorial experiments.

Figure 1 shows examples of the groupings of main, first-order, and higher-order effects for three factors at two and three levels.

TWO LEVELS PER FACTOR

A, B, C	MAIN EFFECTS
AB, AC, BC	1ST–ORDER INTERACTIONS
ABC	HIGHER–ORDER INTERACTION

THREE LEVELS PER FACTOR

A, B, C, A^2, B^2, C^2	MAIN EFFECTS
AB, AC, AB^2, AC^2, BC, A^2B, BC^2, A^2C, CB^2, A^2B^2, A^2C^2, B^2C^2	1ST–ORDER INTERACTIONS
ABC, ABC^2, AB^2C, AB^2C^2, A^2BC, A^2BC^2, A^2B^2C, $A^2B^2C^2$	HIGHER–ORDER INTERACTIONS

Figure 1. Main Effects and Interactions

TABLE 6. Effect/Interaction Summary

N NUMBER OF FACTORS	P = 2 Levels Per Factor			P = 3 Levels Per Factor		
	Main Effects	1st Order	Higher Order	Main Effects	1st Order	Higher Order
2	2	1	0	4	4	0
3	3	3	1	6	12	8
4	4	6	5	8	24	48
5	5	10	16	10	40	192
6	6	15	42	12	60	656
7	7	21	99	14	84	2088
8	8	28	219	16	112	6432
9	9	36	466	18	144	19520
10	10	45	968	20	180	58848

A fractional factorial design, sometimes called a fractional replication, is a portion or a fraction of a complete factorial experiment. In a fractional replicate, certain interactions cannot be separated from other interactions. This is the price that is paid for reducing the number of experimental trials. Interactions or effects that cannot be separated are said to be aliased or confounded.

The use of fractional factorial experiments is based on the assumption that higher-order interactions are insignificant and need not be examined in detail. For example, consider an experiment in which main effect A is aliased with interaction BCD. When data are collected, the experimenter estimates the response caused by effect A when he is actually estimating a response caused by effects A and BCD together. There is no way to know if the response is due only to A or if effect BCD plays a significant part in the response. Thus, effects A and BCD are not separable. The assumption in a fractional factorial experiment is that the contribution caused by BCD would be negligible.

A full factorial experiment is useful when an experimenter requires that:

1. Every main effect of every factor be estimated independently of every other one.
2. The dependence of the effect of every factor upon the levels of the others (the interaction) be determined.
3. The effects be determined with maximum precision.

If an experimenter does not require this level of detail, or if faced with time or budget limitations that prohibit a full factorial experiment, fractional factorial designs are available. The primary assumption in the use of a fractional factorial experiment is that higher-order interactions are insignificant. If this assumption is not valid for a particular experiment, a fractional factorial design should not be used. In most human factors experiments, however, this is a reasonable assumption and can result in a significant reduction in the number of experimental trials required.

Interactio that are assumed to be insignificant can be used to define the aliasing or confounding used in the fractional factorial design. The concept of aliasing is discussed below.

ALIASING

OVERVIEW

Each successive step in fractionating a full factorial design, or dividing it into blocks, requires that an additional effect referred to as a defining contrast be defined for the fractional factorial design. Thus, a two-level, one-half design requires one defining contrast to be defined by the experimenter;

while a one-fourth design requires two defining contrasts, and so on. The defining contrasts must be selected by the experimenter to meet the requirements of the design.

The selection of defining contrasts is important in the design of a fractional factorial experiment. In a given experiment, the value of aliased terms cannot be estimated; thus, no term of interest to the experimenter should be selected as a defining contrast.

Defining contrasts are usually selected to avoid aliasing main effects with other main effects. In a sequential design, however, it may be desirable to alias two main effects. For example, if the experimenter suspects that two factors, A and E, are not significant, he might design the first pilot experiment so that A and E are confounded. If the data from this pilot experiment show that the estimated values of A and E are not significant, then the experimenter's suspicions are confirmed. These two factors can be dropped, thus reducing the experiment size for the next pilot experiment.

The defining contrasts can be described by identities that specify which effects are to be confounded. The experimenter does not have a completely free hand in the selection of these defining contrasts. Unless the selected defining contrasts are linearly independent, some product of the defining contrasts in generating the alias set will result in a member of the alias set that is the same as the nonindependent defining contrast selected. This indicates that the nonindependent defining contrast is redundant, and the experimenter has selected fewer defining contrasts than planned. This results in a larger experiment block size than desired. In this case, it is necessary to redefine the nonindependent defining contrast so that a set of independent defining contrasts is selected.

The following paragraphs provide background for the generation of the alias set and development of alias summaries. These operations are performed within the computer program, and an understanding of this material is not necessary to use the program.

OPERATIONS WITH ALIASES

Assuming each of N factors will be varied over P levels, the set of fractional factorial experiments considered here is the $1/P^M$ designs, where M is a positive integer. Thus two-level designs might be 1/2, 1/4, 1/8, 1/16, etc. Three-level designs might be 1/3, 1/9, 1/27, 1/81, etc. In general, a $1/P^M$ design requires M defining contrasts. Specifying the defining contrasts is an important problem in designing fractional factorial experiments. One way to specify the defining contrasts is to describe which effects are to be confounded.

For example, if effects AB and CD are to be confounded, the user may specify the defining contrast as AB = CD. Defining contrasts may also be described in terms of the identity effect, I. This is accomplished by multiplying both sides of the equation in this example by AB, yielding $A^2B^2 = ABCD$. Assuming a two-level problem, apply modulo 2 arithmetic to the exponents of the factors $A^2B^2 = A^0B^0 = I = ABCD$. If the effects to be confounded are $A^2B = CD$ in a three-level problem, first multiply both sides by A^2B using modulo 3 arithmetic on the exponents. This gives

$$(A^2B)(A^2B) = A^2BCD$$

$$A^4B^2 = AB^2 = A^2BCD$$

Multiply both sides again by A^2B, giving $(AB^2)(A^2B) = (A^2BCD)(A^2B)$

or $\quad A^3B^3 = I = A^4B^2CD = AB^2CD$

or $\quad I = AB^2CD.$

Each effect will be aliased with $(P^M - 1)$ other effects. For $1/P^M$ designs, M must be less than or equal to (N - 1). As the number of defining contrasts increases, the number of effects aliased with each effect increases rapidly as shown in Table 7.

TABLE 7. Number of Effects Aliased

DESIGN	P = No. of Levels	M	No. of Defining Contrasts	No. of Effects Aliased With Each Effect
1/2	2	1	1	1
1/4	2	2	2	3
1/8	2	3	3	7
1/16	2	4	4	15
1/32	2	5	5	31
1/64	2	6	6	63
1/128	2	7	7	127
1/3	3	1	1	2
1/9	3	2	2	8
1/27	3	3	3	26
1/81	3	4	4	80
1/243	3	5	5	242
1/729	3	6	6	728
1/2187	3	7	7	2186

The number of effects aliased with each effect (such as a main effect) increases rapidly as smaller fractional factorial designs are considered. Thus, it becomes difficult to select defining contrasts that avoid aliasing main effects with other main effects in this case.

The total alias combination set may be generated by considering all combinations of all powers of the individual defining contrasts from 1 to the (P - 1)th power. Thus, if a two-level experiment is being considered (P = 2), only the first power of the defining contrasts is considered in deriving the alias set. For a three-level experiment (P = 3), both first and second powers of the defining contrasts are considered in deriving the alias set.

For example, consider a three-level experiment involving four factors ($P = 3$, $N = 4$). Suppose M is selected as a value of 3, resulting in a 1/27 design. From the tabulation, we find that three defining contrasts are required and each effect will be aliased with 26 effects or interactions. The alias set may be derived by representing all the integers from 1 to ($P^M - 1$) in base P arithmetic representation (1 to 26 in this example expressed in base 3 arithmetic).

1 = 001	10 = 101	19 = 201
2 = 002	11 = 102	20 = 202
3 = 010	12 = 110	21 = 210
4 = 011	13 = 111	22 = 211
5 = 012	14 = 112	23 = 212
6 = 020	15 = 120	24 = 220
7 = 021	16 = 121	25 = 221
8 = 022	17 = 122	26 = 222
9 = 100	18 = 200	

Each digit of the base 3 representation is used as the power to which each of the three defining contrasts is raised. For example, the combination 121 indicates that the first and third defining contrasts are raised to the first power while the second defining contrast is squared.

From this list, only those combinations that are in standard form are used, since the other combinations will result in duplications. A combination is in standard form if the leading nonzero exponent is 1. Thus, 120 is in standard form whereas 210 is not.

In our example ($P = 3$, $N = 4$, $M = 3$), let us specify the defining contrasts selected as $I = ABCD = B^2C^2D^2 = A^2B$. The tabulation of combinations in standard form is as shown in Table 8. Note that the exponents are reduced modulo P to arrive at the final alias combinations. Thus, $(A^2D)^2 = A^4D^2 = AD^2$

Table 8. Total Alias Set

POWER SET	DEFINING CONTRAST COMBINATION	TOTAL ALIAS SET
001	A^2B	A^2B
002	$(A^2B)^2$	AB^2
010	B^2C^2D	B^2C^2D
011	$(B^2C^2D)(A^2B)$	A^2C^2D
012	$(B^2C^2D)(A^2B)^2$	ABC^2D
020	$(B^2C^2D)^2$	BCD^2
021	$(B^2C^2D)^2(A^2B)$	$A^2B^2CD^2$
022	$(B^2C^2D)^2(A^2B)^2$	ACD^2
100	$ABCD$	$ABCD$
101	$(ABCD)(A^2B)$	B^2CD
102	$(ABCD)(A^2B)^2$	A^2CD
110	$(ABCD)(B^2C^2D)$	AD^2
111	$(ABCD)(B^2C^2D)(A^2B)$	BD^2
112	$(ABCD)(B^2C^2D)(A^2B)^2$	A^2D^2
120	$(ABCD)(B^2C^2D)^2$	AB^2C^2
121	$(ABCD)(B^2C^2D)^2(A^2B)$	C^2
122	$(ABCD)(B^2C^2D)^2(A^2B)^2$	A^2BC^2
200	$(ABCD)^2$	$A^2B^2C^2D^2$
201	$(ABCD)^2(A^2B)$	AC^2D^2
202	$(ABCD)^2(A^2B)^2$	BC^2D^2
210	$(ABCD)^2(B^2C^2D)$	A^2BC
211	$(ABCD)^2(B^2C^2D)(A^2B)$	AB^2C
212	$(ABCD)^2(B^2C^2D)(A^2B)^2$	C
220	$(ABCD)^2(B^2C^2D)^2$	A^2D
221	$(ABCD)^2(B^2C^2D)^2(A^2B)$	ABD
222	$(ABCD)^2(B^2C^2D)^2(A^2B)^2$	B^2D

modulo 3. Modulo P is merely the remainder when the number is divided by P (e.g., 4 modulo 3 = 1, 12 modulo 3 = 0, 13 modulo 3 = 1, etc.).

In our example for our experiment design, we assigned three defining contrasts. The total alias set was then derived (26 in this case), which represents the combinations applicable to this design. The experimenter must now be concerned with how the individual effects and interactions are aliased.

ALIAS SUMMARY

The primary concern of the experimenter is directed toward examining how all main effects and first-order interactions are aliased. The aliasing for any effect can be found by multiplying the effect by the total alias set (applying modulo P arithmetic to the factor exponents).

For example, consider a design consisting of 6 factors each at 2 levels with an M of 2. This is a one-fourth design, and two defining contrasts must be specified by the experimenter. Assume that the identities selected are I = ABCE = ABDF. Following the rules given in the previous section, we find that each effect is aliased with three effects; and the complete alias set consists of ABCE, ABDF, and CDEF. The main effects and first-order interactions and how they are aliased are illustrated in Table 9.

Table 9. Alias Example

EFFECT	ALIASED WITH:		
A	BCE	BDF	ACDEF
B	ACE	ADF	BCDEF
C	ABE	ABCDF	DEF
D	ABCDE	ABF	CEF
E	ABC	ABDEF	CDF
F	ABCEF	ABD	CDE
AB	CE	DF	ABCDEF
AC	BE	BCDF	ADEF
AD	BCDE	BF	ACEF
AE	BC	BDEF	ACDF
AF	BCEF	BD	ACDE
BC	AE	ACDF	BDEF
BD	ACDE	AF	BCEF
BE	AC	ADEF	BCDF
BF	ACEF	AD	BCDE
CD	ABDE	ABCF	EF
CE	AB	ABCDEF	DF
CF	ABEF	ABCD	DE
DE	ABCD	ABEF	CF
DF	ABCDEF	AB	CE
EF	ABCF	ABDE	CD

Individual effects or interactions can be examined by multiplying the particular effect by each member of the alias set. For example, with I = ABCE = ABDF = CDEF, the interaction EF can be found to be aliased as

$$(I)(EF) = (ABCE)(EF) = (ABDF)(EF) = (CDEF)(EF)$$
$$EF = ABCE^2F = ABDEF^2 = CDE^2F^2$$
$$EF = ABCF = ABDE = CD$$

when all exponents are reduced modulo 2.

If the experiment becomes large, it may be difficult to read the alias summary as shown in Table 9. Therefore, an abbreviated summary (Table 10) is provided to show how each main effect and first-order interaction is aliased with main effects and first-and higher-order interactions. An examination of this table shows that all main effects are aliased only with higher-order interactions. This is an acceptable design for a fractional factorial experiment. Refer to Table 9 to find the specific aliased terms. The particular design acceptability criteria depend upon the problem being studied.

DESIGN EVALUATION

Once the alias summary has been generated, the experimenter must determine if the design is acceptable. The acceptability of a design depends upon the aliasing of those effects considered to be significant to the experimenter. If an insignificant effect is aliased with a significant effect, the design is considered to be a good design. If a few significant effects are aliased, however, the user may define another design or he might use the current design and let the data analysis indicate if an effect that consists of the combination of two potentially significant effects is significant. If a combined effect is significant, the design can be refined to perform the required effect separation.

Once an acceptable design has been generated, the specific experimental units used to collect data must be found. This collection of experimental units is called the basic experimental block.

Table 10. Abbreviated Alias Summary

EFFECT	MAIN	1ST ORDER	HIGHER ORDER
A	0	0	3
B	0	0	3
C	0	0	3
D	0	0	3
E	0	0	3
F	0	0	3
AB	0	2	1
AC	0	1	2
AD	0	1	2
AE	0	1	2
AF	0	1	2
BC	0	1	2
BD	0	1	2
BE	0	1	2
BF	0	1	2
CD	0	1	2
CE	0	2	1
CF	0	1	2
DE	0	1	2
DF	0	2	1
EF	0	1	2

BASIC BLOCK DEFINITION

Once the total alias set has been defined, the specific treatment combinations used to collect data must be found. The details of the construction of this block may be skipped by the novice user.

The M members of the defining contrast set are used to generate the block of treatments and are consequently called generators. If the generators are denoted by

$G_i = A^{a_i}B^{b_i}C^{c_i}\ldots \quad i = 1, 2, \ldots, M$, then the levels in the factorial combinations $x_1x_2x_3\ldots$ selected for the block satisfy simultaneously the M equations

$$a_ix_1 + b_ix_2 + c_ix_3 + \ldots = 0 \quad (\text{modulo } P)$$

$$i = 1, 2, \ldots, M$$

Similar equations in which 1, . . ., (P - 1) is used in place of 0 are equally valid; however, the set of treatments defined using the 0, called the Basic Block or the principal block, will be used here.

Consider the one-fourth replicate of an experiment with six factors at two levels, where the defining contrasts are I = ABCE = ABDF. (The total alias set is I = ABCE = ABDF = CDEF.) The defining contrasts define two generating equations:

$$G_1 = A^1B^1C^1D^0E^1F^0$$
$$G_2 = A^1B^1C^0D^1E^0F^1$$

The simultaneous equations to be solved are:

$$x_1 + x_2 + x_3 + x_5 = 0 \text{ modulo } 2$$
$$x_1 + x_2 + x_4 + x_6 = 0 \text{ modulo } 2$$

Each of the $2^6 = 64$ factor combinations is evaluated using this system of equations, and those combinations satisfying the equations form the basic experimental block. Table 11 shows all 26 treatment combinations and those that form the basic block.

Table 11. Basic Experimental Block

EQUATION VALUE															
EFFECT	(1)	(2)	(3)	EFFECT	(1)	(2)	(3)	EFFECT	(1)	(2)	(3)	EFFECT	(1)	(2)	(3)
* 000000	0	0	0	010000	1	1	0	100000	1	1	0	* 110000	0	0	0
000001	0	1	1	010001	1	0	1	100001	1	0	1	110001	0	1	1
000010	1	0	1	010010	0	1	1	100010	0	1	1	110010	1	0	1
000011	1	1	0	* 010011	0	0	0	* 100011	0	0	0	110011	1	1	0
000100	0	1	1	010100	1	0	1	100100	1	0	1	110100	0	1	1
* 000101	0	0	0	010101	1	1	0	100101	1	1	0	* 110101	0	0	0
000110	1	1	0	* 010110	0	0	0	* 100110	0	0	0	110110	1	1	0
000111	1	0	1	010111	0	1	1	100111	0	1	1	110111	1	0	1
001000	1	0	1	011000	0	1	1	101000	0	1	1	111000	1	0	1
001001	1	1	0	* 011001	0	0	0	* 101001	0	0	0	111001	1	1	0
* 001010	0	0	0	011010	1	1	0	101010	1	1	0	* 111010	0	0	0
001011	0	1	1	011011	1	0	1	101011	1	0	1	111011	0	1	1
001100	1	1	0	* 011100	0	0	0	* 101100	0	0	0	111100	1	1	0
001101	1	0	1	011101	0	1	1	101101	0	1	1	111101	1	0	1
001110	0	1	1	011110	1	0	1	101110	1	0	1	111110	0	1	1
* 001111	0	0	0	011111	1	1	0	101111	1	1	0	* 111111	0	0	0

*IDENTIFIES THOSE TREATMENT COMBINATIONS WHICH WILL BE INCLUDED IN THE BASIC EXPERIMENTAL BLOCK

The basic block (or observation vector) for the example is given in Table 12. Note that 0 indicates the factor is at its low level whereas a 1 indicates a factor is at its highest level. Once the basic block is defined, the experimenter must collect the experimental data. Data collection procedures are discussed in the next section.

Table 12. Basic Block Summary

EXPERIMENTAL UNIT	FACTOR LEVEL					
	A	B	C	D	E	F
1	0	0	0	0	0	0
2	0	0	0	1	0	1
3	0	0	1	0	1	0
4	0	0	1	1	1	1
5	0	1	0	0	1	1
6	0	1	0	1	1	0
7	0	1	1	0	0	1
8	0	1	1	1	0	0
9	1	0	0	0	1	1
10	1	0	0	1	1	0
11	1	0	1	0	0	1
12	1	0	1	1	0	0
13	1	1	0	0	0	0
14	1	1	0	1	0	1
15	1	1	1	0	1	0
16	1	1	1	1	1	1

DATA COLLECTION

Using the experimental units defined in the basic experimental block, the data collection process is relatively straightforward. The different combinations in the basic block are tested, and the response value is measured.

No consideration has been given to the specific order in which these experimental units are to be run. The general procedure is to select random combinations until each of the experiments in the basic block has been run. This is acceptable unless the experimenter considers a change in the system over time. A system change can be overcome by dividing the basic block into smaller blocks. The assumption is made that the system is relatively homogeneous within each block. Techniques for the construction of blocks are identical to those used to build the alias set. An effect is selected, and the effect equation is generated. For example, consider effect AC. The value of the effect equation for AC equals 0 modulo 2 goes into one block, and the effect equation for AC equals 1 modulo 2 goes into a second block. This causes effect AC to be no longer measurable, i.e., the experimenter cannot know if a response is due to the interaction AC or to a change between blocks.

Blocking procedures are not included in this program. This capability can be added at a later date. The inclusion of this feature, however, requires a trained, experienced user.

Once the data have been collected, they must be analyzed to identify significant effects. This analysis consists of an analysis of variance (ANOVA) or of a regression analysis. Because details concerning ANOVA and regression analysis methods may be found in any statistical analysis text, they have not been included here.

REFINING DESIGNS

When data have been collected and analyzed from a fractional factorial experiment, the experimenter may determine that he wishes to further examine certain effects or interactions that were confounded in the original design. Finding a new design in which these effects are separated is called refining the design. This is accomplished by dividing one of the effects to be separated from the other to yield a member of the alias set. This division is defined as a subtraction of corresponding exponents where an exponent is increased by P whenever the subtrahend would have been larger than the minuend. For example, if P=3,

$$201/102 \;\Rightarrow\; \begin{array}{r} 201 \\ -\,102 \\ \hline \end{array} \;\Rightarrow\; \begin{array}{r} 204 \\ -\,102 \\ \hline 102 \end{array}$$

The member of the power set that was used to generate this member of the alias set is examined for non-zero columns. Removal of any one of the defining contrasts represented by these columns results in separating the two effects. (i.e., If the member of the power series was found to be 210, removal of either the first or the second defining contrast would accomplish the desired separation.)

Removal of a defining contrast results in doubling the number of trials in a two-level experiment, and tripling the number of trials in a three-level experiment. This is the price paid for reducing the confounding.

IRREGULAR FRACTIONAL FACTORIAL EXPERIMENTS

The generation of fractional experiments uses a 1 in P^N design, i.e., a 1/8, a 1/27, or a 1/64 design. Although any fraction such as k in P^N may be constructed, these designs have many problems. Consider the case with five factors at two levels, but with only 24 experimental units available. One possibility would be a 3/4 design based on using a 1/2 and 1/4 replicate design. If this is used, the total design will have highly correlated estimates that could lead to extremely difficult tests of significance.

Another approach would be to use a 1/2 replicate and a 1/2 replicate of the unused portion of the larger design. Because of confounding, however, this design provides less information to the experiment than the 1/2 replicate alone. For these reasons, fractional designs other than a 1 in P^N are not advantageous.

PREDEFINED DESIGNS

An experimenter frequently requires a design for which he is unable to find the appropriate aliasing. This section includes a set of predefined designs that allow for all main effects to be measurable. Main effects are aliased with only high-order interactions. Also, most two-factor interactions are measurable.

To aid the user, the different experimental designs are identified by the notation L.F.S., where L is the number of levels per factor, 2 or 3; F is the number of factors; and S is the number of experimental units in the fractional design (e.g., 2.4.8 = 2 levels, 4 factors, and 8 units). The sources of these predefined designs are C&C (Cochran and Cox, 1957), NBS #48 and NBS #54.

Design 2.4.8

2^4 factorial in 8 units
1/2 replicate
I = ABCD
C&C, p. 276

Design 2.5.8

2^5 factorial in 8 units
1/4 replicate
I = ABE = CDE
C&C, p. 277

Design 2.5.16

2^5 factorial in 16 units
1/2 replicate
I = ABCDE
C&C, p. 277

Design 2.6.8

2^6 factorial in 8 units
1/8 replicate
I = ACE = ADF = BCF
C&C, p. 278

Design 2.6.16

2^6 factorial in 16 units
1/4 replicate
I = ABCE = ABDF
C&C, p. 278

Design 2.6.32

2^6 factorial in 32 units
1/2 replicate
I = ABCDEF
C&C, p. 279

Design 2.7.8

2^7 factorial in 8 units

1/16 replicate

I = ABG = ACE = ADF = BCF

C&C, p. 280

Design 2.7.16

2^7 factorial in 16 units

1/8 replicate

I = ABCD = ABEF = ACEG

C&C, p. 280

Design 2.7.32

2^7 factorial in 32 units

1/4 replicate

I = ABCDE = ABCFG

C&C, p. 281

Design 2.7.64

2^7 factorial in 64 units

1/2 replicate

I = ABCDEFG

C&C, p. 283

Design 2.8.16

2^8 factorial in 16 units

1/16 replicate

I = ABCD = ABEF = ABGH = ACEH

C&C, p. 285

Design 2.8.32

2^8 factorial in 32 units

1/8 replicate

I = BCDH = BDFG = ABCEF

C&C, p. 286

Design 2.8.64

2^8 factorial in 64 units

1/4 replicate

I = ABCEG = ABDFH

C&C, p. 287

Design 2.8.128

2^8 factorial in 128 units

1/2 replicate

I = ABCDEFGH

C&C, p. 288

Design 2.9.32

2^9 factorial in 32 units

1/16 replicate

I = ABCD = ABEF = BCEG = EFGHJ

NBS #48, p. 43

Design 2.9.64

2^9 factorial in 64 units

1/8 replicate

I = ABEGHJ = ACFGJ = ABCD

NBS #48, p. 33

Design 2.9.128

2^9 factorial in 128 units

1/4 replicate

I = ABCEGJ = ABDFHJ

NBS #48, p. 24

Design 2.9.256

2^9 factorial in 256 units

1/2 replicate

I = ABCDEFGHJ

NBS #48, p. 17

Design 2.10.64

2^{10} factorial in 64 units

1/16 replicate

I = ABCDJK = ABEFJ = BCEGJK = ABCDEFGH

NBS #48, p. 44

Design 2.10.128

2^{10} factorial in 128 units

1/8 replicate

I = ABEGHJ = ACFGJK = ABCDK

NBS #48, p. 36

Design 2.10.256

2^{10} factorial in 256 units

1/4 replicate

I = ABCDEFG = ABCDHJK

NBS #48, p. 29

Design 2.10.512

2^{10} factorial in 512 units

1/2 replicate

I = ABCDEFGHJK

Design 3.4.27

3^4 factorial in 27 units

1/3 replicate

I = ABCD

NBS #54, p. 11

Design 3.5.81

3^5 factorial in 81 units

1/3 replicate

I = ABCD

NBS #54, p. 11

Design 3.6.81

3^6 factorial in 81 units

1/9 replicate

I = ACDE = BC^2DE^2F

NBS #54, p. 19

Design 3.6.243

3^6 factorial in 243 units

1/3 replicate

I = AB^2CDE^2F

NBS #54, p. 14

Design 3.7.81

3^7 factorial in 81 units

1/27 replicate

$I = ABCDEF^2G = BC^2EF^2G = ABCEG^2$

NBS #54, p. 25

Design 3.7.243

3^7 factorial in 243 units

1/9 replicate

$I = ABCDEG = D^2EF^2G^2$

NBS #54, p. 20

Design 3.7.729

3^7 factorial in 729 units

1/3 replicate

$I = AB^2CDE^2FG$

NBS #54, p. 17

Design 3.8.81

3^8 factorial in 81 units

1/81 replicate

$I = ACDEF^2G = BC^2EF^2G = ABCEG^2$

$= AB^2CD^2E^2F^2G^2H^2$

NBS #54 , p. 31

Design 3.8.243

3^8 factorial in 243 units

1/27 replicate

$I = BCDEFG = ACDE^2F^2H = ABD^2E^2F$

NBS #54, p. 27

Design 3.8.729

3^8 factorial in 729 units

1/9 replicate

$I = ABCDEH^2 = CD^2EF^2G^2$

NBS #54, p. 23

Design 3.9.81

3^9 factorial in 81 units

1/243 replicate

$I = BCDEFG = ACDE^2F^2H$

$= ABD^2E^2FJ = AB^2C^2DF$

$= ABC^2EF^2$

NBS #54, p. 36

Design 3.9.243

3^9 factorial in 243 units

1/81 replicate

$I = BCDEFG = ACDE^2F^2H$

$= ABD^2E^2FJ = AB^2C^2DF$

NBS #54, p. 34

Design 3.9.729

3^9 factorial in 729 units

1/27 replicate

$I = BCDEFG = ACDE^2F^2H$

$= ABD^2E^2FJ$

NBS #54, p. 29

USER'S APPENDIX GUIDE WITH EXAMPLES

INTRODUCTION

The appendix describes the procedures for using the sequential design computer program. The "conversational mode" of the program operation is illustrated. The functions of each of the program segments are explained, and a listing is included of the program input and output for an example from each segment.

The use of this program is demonstrated on a problem related to the MISVAL project (Missile Launch Envelope Technology Development Program being conducted by the Air Force Wright Aeronautical Laboratories at Wright-Patterson Air Force Base). This demonstration provides a detailed exercise in the use of this program in a real-world problem. A tape of the Automated Interactive Sequential Experimental Design program source listing in Fortran 4.5 can be obtained from AFAMRL/HEF, ATTN: Dr. Robert G. Mills, W-PAFB, OH 45433.

SYSTEM STRUCTURE

The automated sequential design program is divided into six program segments. Upon execution of the program, a display menu is presented. The user may select one of the six by inputting the number of the segment he wishes. The program echoes the input and requests the user to input an identification label to identify this run. The I.D. label may be any alphanumeric string.

This menu, entry request, and I.D. label request occur whenever a segment is completed and the program is ready to enter another segment. The actual text displayed and a system "walk-through" will be included with the explanation of the use of each segment in the following sections.

BASIC TERMINOLOGY

Segment 1--Basic Terminology--provides the user with a basic introduction to the process of experimental design. A description of the program assumptions, vocabulary, and a discussion of the rationale behind screening designs are provided. This material is essentially a tutorial for the user who is unfamiliar with experimental design. Once the user is acquainted with the design process, he should not have to enter this segment except for an occasional review session. User input is explained in this segment.

****

WELCOME TO THE SCREENING DESIGNS PROGRAMS.
YOU MAY ENTER ONE OF THE PROGRAM SEGMENTS:

1. BASIC TERMINOLOGY
2. PROBLEM DEFINITION
3. ACTUAL EXPERIMENTAL DESIGN
4. DATA ANALYSIS
5. EXPERIMENTAL REFINEMENT
6. EXIT

ENTER THE SEGMENT NUMBER YOU WANT AND HIT RETURN
1
YOUR ENTRY WAS: 1--BASIC TERMINOLOGY

PLEASE ENTER THIS RUN I.D. STRING.
BASIC TERMINOLOGY TEST RUN

WELCOME TO THE DESIGN OF SCREENING EXPERIMENTS PROGRAM. THIS PROGRAM ASSUMES THAT YOUR OBJECTIVE IS TO DETERMINE FACTORS THAT PRODUCE A CERTAIN RESULT AND THE RELATIVE IMPORTANCE OF THESE FACTORS. IN THIS CASE YOU HAVE ALREADY OBTAINED BY OBSERVATION AND INTUITION AN IDEA OF THOSE FACTORS THAT MAY POSSIBLY INFLUENCE THE OUTCOME OF THE EXPERIMENT. IN THIS CASE, FRACTIONAL DESIGNS ARE OF REAL VALUE. THEY MAY BE USED TO DETERMINE WHICH OF THE POSSIBLE FACTORS ARE OF IMPORTANCE RELATIVE TO A GIVEN ERROR OF PREDICTION. ONCE THESE FACTORS HAVE BEEN DISCOVERED, IT IS NECESSARY TO PERFORM DETAILED WORK ON THE FACTORS, POSSIBLY EVEN ONE AT A TIME IN ORDER TO FORMULATE A LAW RELATING RESPONSE TO THE LEVEL FOR EACH FACTOR.

HIT RETURN WHEN READY TO CONTINUE.

BASIC TERMINOLOGY TEST RUN
****

SCREENING DESIGNS -- A CLASS OF FRACTIONAL FACTORIALS -- ARE SYSTEMATIC DATA COLLECTION PLANS THAT ENABLE THE EFFECTS OF A VERY LARGE NUMBER OF FACTORS TO BE ESTIMATED ECONOMICALLY. SCREENING DESIGNS ARE USED PRIMARILY IN THE SECOND PHASE OF A TOTAL RESEARCH PROGRAM WHERE THEY ARE INTENDED TO DETERMINE WHICH OF THE GREAT MANY FACTORS HAVE NON-TRIVIAL EFFECTS ON THE PERFORMANCE OF A PARTICULAR TASK. SCREENING DESIGNS ARE TO BE USED TO IDENTIFY IMPORTANT FACTORS, NOT TO OBTAIN AN ACCURATE REPRESENTATION OF THE EXPERIMENTAL SPACE. THIS LATTER OPERATION WILL OCCUR IN SUBSEQUENT PHASES OF THE RESEARCH PROGRAM.

HIT RETURN TO CONTINUE.

BASIC TERMINOLOGY TEST RUN

****

THE SCREENING DESIGNS PROVIDE A MEANS OF EXAMINING A GREAT NUMBER OF FACTORS WITH THE MAXIMUM AMOUNT OF INFORMATION WITH A MINIMUM AMOUNT OF REDUNDANCE AND RELATIVELY FEW TRIALS. WHAT THE RESULTS FROM MANY LITTLE TRADITIONAL EXPERIMENTS CANNOT DO, BUT WHICH RESULTS FROM THE SCREENING DESIGN CAN DO IS TO ORDER THE FACTORS ACCORDING TO THE SIZE OF THEIR EFFECTS AND TO DISCOVER INTERACTIONS AMONG FACTORS THAT APPEAR WITHIN THE SAME EXPERIMENT. SCREENING DESIGNS DO ALL THIS ECONOMICALLY FOR THEY CAN BE USED TO STUDY FACTORS WITH A SMALL NUMBER OF TRIALS (ALTHOUGH THE SIZE OF THE DESIGNS IN THIS PROGRAM WILL ALL BE EQUAL TO A POWER OF 2 OR 3). THE EFFECTS OBTAINED FROM SCREENING STUDIES NOT ONLY PERMIT THE RANKING OF FACTOR EFFECTS ON A QUANTITATIVE SCALE, BUT CAN PROVIDE AN EQUATION APPROXIMATING THE EXPERIMENTAL SPACE IF THAT SPACE CAN BE REPRESENTED BY A LINEAR MODEL.

HIT RETURN TO CONTINUE.

THE BEAUTY OF USING A SCREENING DESIGN IS THAT ONCE THE IMPORTANT FACTORS HAVE BEEN IDENTIFIED (STEP ONE), THE SAME DATA CAN BE USED, IF SUPPLEMENTED BY RELATIVELY FEW ADDITIONAL TRIALS AT NEW EXPERIMENTAL CONDITIONS, TO COMPLETE A RESPONSE SURFACE (STEP TWO) CAPABLE OF ACCURATELY APPROXIMATING THE EXPERIMENTAL SPACE DEFINED BY THE ORIGINAL SET OF FACTORS.

IN USING A SCREENING DESIGN, THE EXPERIMENTER MUST ASK CERTAIN QUESTIONS ABOUT EACH FACTOR.

DOES THE FACTOR HAVE AN EFFECT ON PERFORMANCE?
DOES THE FACTOR ACCOUNT FOR A MEANINGFUL PROPORTION OF THE VARIANCE IN THE EXPERIMENT?
DOES INCLUDING THE FACTOR MATERIALLY IMPROVE THE ABILITY TO PREDICT PERFORMANCE UNDER OPERATIONAL CONDITIONS?
COULD THE OBSERVED EFFECT HAVE BEEN DUE TO CHANCE?
CAN THE CUMULATIVE EFFECTS OF A LARGE NUMBER OF NON-CRITICAL FACTORS BE IGNORED?
DO YOU WANT TO REVIEW THIS DISCUSSION OF SCREENING DESIGNS?
NO.

BASIC TERMINOLOGY TEST RUN

****

```
YOU WILL BE ASKED A SERIES OF QUESTIONS.
SOME OF THESE REQUIRE ONLY A YES OR NO RESPONSE.  YOU MAY ENTER A Y OR YES
OR N OR NO TO THESE QUESTIONS.
DO YOU WANT TO CONTINUE WITH THESE BASIC INSTRUCTIONS?
YES
```

The user may review these basic instructions. A "NO" response would skip the remainder of this segment.

```
BASIC TERMINOLOGY TEST RUN
******************************************************************************
THESE INSTRUCTIONS CONSIST OF A DEFINITION OF YOUR RESPONSES FOR NUMBERS AND AN
EXPLANATION OF THE VARIOUS TERMS USED IN THE DESIGN OF EXPERIMENTS.

WHEN A NUMBER IS REQUESTED FOR INPUT, YOU MUST ENTER THE VALUE AS + 1 OR -2 OR
96, ETC., OR 11.67 OR -3.26.  THE NUMBER CANNOT BE INPUT AS A FRACTION (1/2).
I WILL ECHO EACH VALUE INPUT AND GIVE YOU THE OPPORTUNITY TO CORRECT IT IF NECESSARY.
INPUT A NUMBER OF YOUR OWN CHOICE AS A TEST
112.345
IS THIS INPUT CORRECT: 112.345
NO
INPUT A NUMBER OF YOUR OWN CHOICE AS A TEST
99.76
IS THIS INPUT CORRECT: 99.76
YES
WE WILL NOW DEFINE THE VARIOUS TERMS USED IN THE DESIGN OF EXPERIMENTS PROGRAM.
DO YOU WANT TO REVIEW THIS INTRODUCTION?
NO.
```

Data input is critical to the use of this program. Data are echoed and the user may change/correct his response. Note that the user had the option to change the input response until satisfied. The program recognizes incorrectly formatted input and continues to prompt the user until a valid response is made.

```
BASIC TERMINOLOGY TEST RUN
***************************************************************************
THE FOLLOWING IS A LIST OF TERMS USED IN EXPERIMENTAL DESIGN.


ALIAS
     EFFECT OF A FACTOR WHICH CANNOT BE DISTINGUISHED FROM THAT OF ANOTHER FACTOR.

ALPHA
     PROBABILITY OF REJECTING A HYPOTHESIS WHEN IT IS TRUE.

BETA PROBABILITY OF ACCEPTING A HYPOTHESIS WHEN IT IS FALSE.

CONFOUNDING
     AN EXPERIMENTAL ARRANGEMENT IN WHICH CERTAIN EFFECTS CANNOT BE DISTINGUISHED
     FROM OTHERS.

CORRELATION COEFFICIENT (PEARSON R)
     THE SQUARE ROOT OF THE PROPORTION OF TOTAL VARIATION ACCOUNTED FOR BY
     LINEAR REGRESSION.

CORRELATION INDEX R
     THE SQUARE ROOT OF THE PROPORTION OF TOTAL VARIATION ACCOUNTED FOR BY
     THE REGRESSION EQUATION OF THE DEGREE BEING FITTED TO THE DATA.


HIT RETURN WHEN READY TO CONTINUE.
```

```
BASIC TERMINOLOGY TEST RUN
**********************************************************************************
DEGREES OF FREEDOM
        IN THIS PROGRAM, ONE LESS THAN THE NUMBER OF VALUES TO COMPUTE THE SUM OF
        SQUARES.
EFFECT
        CHANGE IN RESPONSE DUE TO A CHANGE IN THE LEVEL OF A FACTOR.
ERRORS
        TYPE I:  REJECTION OF A HYPOTHESIS WHEN TRUE.
        TYPE II:  ACCEPTING A HYPOTHESIS WHEN FALSE.
EXPERIMENTAL MODEL
        HYPOTHESIZED EQUATION TO DESCRIBE THE RESPONSE AS A FUNCTION OF THE
        TREATMENT.
FACTORIAL EXPERIMENT
        AN EXPERIMENT IN WHICH ALL LEVELS OF EACH FACTOR IN THE EXPERIMENT
        ARE COMBINED WITH ALL LEVELS OF EVERY OTHER FACTOR.
FRACTIONAL REPLICATION
        AN EXPERIMENTAL DESIGN IN WHICH ONLY A FRACTION OF A COMPLETE FACTORIAL
        IS RUN.

HIT RETURN WHEN READY TO CONTINUE.
```

```
BASIC TERMINOLOGY TEST RUN
***************************************************************************
F-TEST
       A STATISTICAL TEST TO CHECK FOR EQUAL MEANS BETWEEN TWO POPULATIONS.

INTERACTION
       AN INTERACTION BETWEEN TWO FACTORS MEANS THAT A CHANGE IN RESPONSE BETWEEN
       LEVELS OF ONE FACTOR IS NOT THE SAME FOR ALL LEVELS OF THE OTHER FACTOR.

MEAN SQUARE ERROR
       SUM OF SQUARES OF THE ERROR DIVIDED BY THE NUMBER OF DEGREES OF FREEDOM
       FOR THE ERROR TERM.

OBSERVATION
       A MEASURED DEPENDENT VARIABLE VALUE.

REGRESSION
       LINEAR -RESPONSE =A*X1+B*X2+C*X3+...+Z*XN
       QUADRATIC -RESPONSE =A*X1+B*X2+..+C*X1*X2+D*X1*X3+..+E*X1**2+F*X2**2+..+Z*XN**2.

REJECTION CRITERIA
       TEST STRUCTURE USED TO REJECT THE NULL HYPOTHESIS.


HIT RETURN WHEN READY TO CONTINUE.
```

```
BASIC TERMINOLOGY TEST RUN
********************************************************************************
R-SQUARED
          SMALL R-SQUARED - SEE CORRELATION COEFFICIENT.
          BIG R-SQUARED - SEE CORRELATION INDEX.
STATISTICAL HYPOTHESIS
          HO:  AN ASSUMPTION ABOUT A POPULATION BEING SAMPLED.
TEST OF HYPOTHESIS
          A RULE BY WHICH A HYPOTHESIS IS ACCEPTED OR REJECTED.
TRIAL
          A SINGLE SET OF FACTOR VALUES APPLIED TO THE EXPERIMENTAL SUBJECT FOR
          WHICH THE RESPONSE IS MEASURED.

DO YOU WANT TO REVIEW THESE DEFINITIONS?
NO


BASIC TERMINOLOGY TEST RUN
********************************************************************************
DO YOU WANT TO RERUN THIS SEGMENT?
NO
```

PROBLEM DEFINITION

Segment 2--Problem Definition--is used by the experimenter to define the particular problem he is studying. This definition includes: (1) the number of factors, (2) the number of levels for each factor, (3) the number of experimental units available, and (4) aliasing information.

Since the process of specifying the defining contrasts that determine the aliasing is critical, the user is offered assistance in the definition of these aliases. In this help section, the strategies behind certain aliasing schemes are described and the user is offered more help for one type of design. The program can provide certain predefined designs.

If the predefined alias set was unacceptable, or if one was not available, the user must input the aliases. Care should be taken that the members of the alias set are linearly independent, since if any member of the alias set is a linear combination of the other members, the experimental block will contain more than the desired number of observations. The program will check for independence of the alias set, and give the user an opportunity to redefine the set.

The user may also have the total alias set displayed. (The total alias set is constructed by forming all possible combinations of the original aliases specified by the user). The alias set may be redefined until the design is acceptable to the user.

The following is an example of the definition and design of a 1/2 replicate of a 2^5 experiment.

```
**************************************************************************
WELCOME TO THE SCREENING DESIGNS PROGRAM.
YOU MAY ENTER ONE OF THE PROGRAM SEGMENTS:

     1.  BASIC TERMINOLOGY
     2.  PROBLEM DEFINITION
     3.  ACTUAL EXPERIMENTAL DESIGN
     4.  DATA ANALYSIS
     5.  EXPERIMENTAL REFINEMENT
     6.  EXIT
ENTER THE SEGMENT NUMBER YOU WANT AND HIT RETURN
2
YOUR ENTRY WAS:  2--PROBLEM DEFINITION

PLEASE ENTER THIS RUN PROBLEM I.D.
PROBLEM DEFINITION AND DESIGN TEST

NOW WE MUST DEFINE THE SPECIFIC PROBLEM
TO BE ANALYZED IN THIS RUN.

HOW MANY LEVELS FOR THE FACTORS?
2
HOW MANY FACTORS ARE INVOLVED?
5
HOW MANY EXPERIMENTAL TRIALS ARE AVAILABLE?
16
2  LEVELS FOR THE FACTORS.  IS THIS CORRECT?
Y
5 FACTORS ARE PRESENT.  IS THIS CORRECT?
Y
16 TRIALS ARE AVAILABLE.  IS THIS CORRECT?
Y

     31 IS THE TOTAL NUMBER OF EFFECTS AND INTERACTIONS.
         OF THESE:
      5 ARE MAIN EFFECTS.
     10 ARE FIRST ORDER INTERACTIONS.
     16 ARE HIGHER ORDER INTERACTIONS.

HIT RETURN WHEN READY TO CONTINUE.
```

```
PROBLEM DEFINITION AND DESIGN TEST
*****************************************************************************
HOW MANY EXPERIMENTAL TRIALS ARE TO BE RUN?
THIS MUST BF SELECTED FROM THE VALUES:
          2      4      8      16      32
16
IS THIS WHAT YOU WANT:  16
YES

FOR AN EXPERIMENT OF THIS SIZE, YOU WILL NEED 1 LINEARLY INDEPENDENT ALIAS(ES)

THE FACTORS IN THE DESIGN MUST BE DESIGNATED AS A,B,C,D, ETC.
THE LETTER I IS RESERVED FOR THE IDENTITY EFFECT.

SINCE EACH FACTOR MUST APPEAR IN A TREATMENT, THE FOLLOWING NOTATION IS USED TO
DESCRIBE THE FACTORS IN A PARTICULAR TRIAL OR ALIAS DEFINITION.
FOR A 2 LEVEL PER FACTOR EXPERIMENT, THE ABSENCE OF A LETTER INDICATES THE FACTOR
IS AT ITS LOW LEVEL.
THE PRESENCE OF A LETTER INDICATES THE FACTOR IS AT ITS HIGH LEVEL.

FOR A 3 LEVEL PER FACTOR EXPERIMENT, THE ABSENCE OF A LETTER IS THE LOW LEVEL,
THE PRESENCE OF THE LETTER INDICATES THE INTERMEDIATE LEVEL, WHILE THE LETTER
FOLLOWED BY A 2 INDICATES THE HIGH LEVEL.

FOR 2 LEVEL PER FACTOR: AC MEANS FACTOR A AT ITS HIGH LEVEL, FACTOR B AT ITS LOW
LEVEL, AND FACTOR C AT ITS HIGH LEVEL.

FOR 3 LEVELS PER FACTOR: A2C MEANS FACTOR A AT ITS HIGH LEVEL, FACTOR B AT ITS LOW
LEVEL, AND FACTOR C AT ITS INTERMEDIATE LEVEL.
DO YOU WANT SOME HELP WITH THE ALIAS DEFINITION?
YES
```

```
PROBLEM DEFINITION AND DESIGN TEST
*******************************************************************
YOU MAY DEFINE ALIASING BY DESCRIBING WHICH EFFECTS ARE TO BE CONFOUNDED, FOR
EXAMPLE, AB=CD.  ANOTHER (MORE COMMON) WAY IS TO DEFINE THE ALIASING IN TERMS
OF THE IDENTITY EFFECT.  THIS IS FOUND BY REPEATEDLY MULTIPLYING EACH SIDE OF
THE EQUATION BY THE LEFT HAND MEMBER, USING MODULO ARITHMETIC ON THE EXPONENTS
UNTIL ALL EXPONENTS ON THE LEFT ARE ZERO.
USING THE ABOVE EXAMPLE, FOR A TWO-LEVEL EXPERIMENT

       (AB)  (AB) = (AB)  (CD)
            A2B2 = ABCD
               I = ABCD MODULO 2
FOR A THREE LEVEL EXPERIMENT
       (AB)  (AB) = (AB)  (CD)
             A2B2 = ABCD
       (AB) (A2B2) = (AB)  (ABCD)
             A3B3 = A2B2CD
                I = A2B2CD MODULO 3

HIT RETURN WHEN READY TO CONTINUE.
```

```
PROBLEM DEFINITION AND DESIGN TEST
********************************************************************************
THE PROPERTIES OF A "GOOD" ALIAS SET ARE DEPENDENT ON THE PARTICULAR EXPERIMENT AND
WHAT YOU HOPE TO ACCOMPLISH.
FOR EXAMPLE, IF YOU SUSPECT THAT TWO OF THE EFFECTS MAY BE OF LITTLE SIGNIFICANCE,
YOU MAY WANT THESE TWO EFFECTS TO BE CONFOUNDED SO THAT THEY MAY BOTH BE ELIMINATED
FROM FUTURE TESTING IF YOUR SUSPICION IS SUPPORTED BY THE ANALYSIS OF THE DATA FROM
THIS PILOT EXPERIMENT.
IN MANY EXPERIMENTS, IT IS DESIRABLE TO HAVE MAIN EFFECTS NOT CONFOUNDED WITH OTHER
MAIN EFFECTS, ON THE ASSUMPTION THAT INTERACTIONS INVOLVING THREE OR MORE FACTORS
(SECOND-OR HIGHER-ORDER INTERACTIONS) CAN BE CONSIDERED NEGLIGIBLE, A DESIGN OF THIS
TYPE PERMITS RAPID ESTIMATION OF MAIN EFFECTS.
CERTAIN PRE-DEFINED DESIGNS ARE AVAILABLE WHICH HAVE ALL MAIN EFFECTS CONFOUNDED
WITH
HIGHER-ORDER INTERACTIONS AND THE MAXIMUM NUMBER OF TWO-FACTOR INTERACTIONS CON-
FOUNDED WITH HIGHER-ORDER INTERACTIONS.

WOULD YOU LIKE SUCH A DESIGN.
YES
```

PROBLEM DEFINITION AND DESIGN TEST

****

BASED ON THE EXPERIMENTAL DESCRIPTION YOU HAVE GIVEN ABOUT THE NUMBER OF FACTORS, THE FACTOR LEVELS, AND THE NUMBER OF TRIALS TO BE USED, THE FOLLOWING DESIGN IS FEASIBLE: DESIGN 2.5.16 1/2 REPLICATE ALIAS DEFINITION:

I=ABCDE

DO YOU WANT TO USE THIS DESIGN?

YES

THE ALIAS SET DEFINED CONTAINS 1 INDEPENDENT MEMBER .

DO YOU WANT TO SEE THE TOTAL ALIAS SET?

NO

WOULD YOU LIKE TO REDEFINE THE ALIASES?

NO

PROBLEM DEFINITION COMPLETED

HIT RETURN WHEN READY TO CONTINUE

REMEMBER THAT THE ALIAS MUST BE OF THE FORM EFFECT 1 = EFFECT 2
THE FIRST ALIAS EFFECT IS INPUT THEN THE SECOND.

ALIAS NO. 1 FIRST TERM

I

ALIAS NO. 1 SECOND TERM

ABCDE

IS THIS CORRECT?

I = ABCDE

Y

THE ALIAS SET DEFINED CONTAINS 1 INDEPENDENT MEMBER.

DO YOU WANT TO SEE THE TOTAL ALIAS SET?

NO

WOULD YOU LIKE TO REDEFINE THE ALIASES?

NO

PROBLEM DEFINITION COMPLETED.

HIT RETURN WHEN READY TO CONTINUE

This is an example of how the alias set is inputted if the predefined alias set was unacceptable or unavailable.

ACTUAL EXPERIMENTAL DESIGN

Segment 3--Actual experimental design uses the previously specified experimental definition (Segment 2) to construct the set of experimental treatments to be run. This set is called the basic experimental block/observation vectors. To aid the experimenter in deciding if the experiment has an acceptable structure, an alias summary is displayed that shows how main effects and first-order interactions are aliased. The user may also have the aliasing of any specific effect displayed.

If the design is unacceptable, the experimenter can rerun the problem definition phase.

The following is an example of the experimental design of the problem defined in Segment 2.

WELCOME TO THE SCREENING DESIGNS PROGRAM.
YOU MAY ENTER ONE OF THE PROGRAM SEGMENTS:

1. BASIC TERMINOLOGY
2. PROBLEM DEFINITION
3. ACTUAL EXPERIMENTAL DESIGN
4. DATA ANALYSIS
5. EXPERIMENTAL REFINEMENT
6. EXIT

ENTER THE SEGMENT NUMBER YOU WANT AND HIT RETURN
3
YOUR ENTRY WAS: 3--ACTUAL EXPERIMENTAL DESIGN

PLEASE ENTER THIS RUN PROBLEM I.D.
ACTUAL EXPERIMENTAL DESIGN DEMONSTRATION

THIS IS A SUMMARY OF THE NUMBER OF MAIN EFFECTS AND FIRST ORDER INTERACTIONS CONFOUNDED WITH EACH MAIN EFFECT AND FIRST ORDER INTERACTION.
MAIN EFFECTS ARE MARKED WITH THE LETTER M, AND THOSE MAIN EFFECTS THAT ARE CONFOUNDED WITH OTHER MAIN EFFECTS ARE FLAGGED WITH AN *.

HIT RETURN WHEN READY TO CONTINUE.

EXPERIMENTAL DESIGN SUMMARY

MAIN	1-ST	HIGHER		EFFECT
0	0	1	M	A
0	0	1		AB
0	0	1		AC
0	0	1		AD
0	0	1		AE
0	0	1	M	B
0	0	1		BC
0	0	1		BD
0	0	1		BE
0	0	1	M	C
0	0	1		CD
0	0	1		CE
0	0	1	M	D
0	0	1		DE
0	0	1	M	E

END OF SUMMARY TABLE

HIT RETURN WHEN READY TO CONTINUE

If any of the main effects had been confounded with another main effect, it would have been flagged with an *.

Note that in this design, none of the main effects or first-order interactions are confounded with any other main effects or first-order interactions.

ACTUAL EXPERIMENTAL DESIGN DEMONSTRATION

```
**************************************************************************
WHICH EFFECT/INTERACTION DO YOU WANT TO SEE?
ENTER THE EFFECT DESCRIPTION.  ENTER A BLANK TO EXIT.
EXAMPLE:  ENTER AB TO SEE WHAT IS ALIASED WITH EFFECT AB.
A
    BCDE
WHICH EFFECT/INTERACTION DO YOU WANT TO SEE?
ENTER THE EFFECT DESCRIPTION.  ENTER A BLANK TO EXIT.
EXAMPLE:  ENTER AB TO SEE WHAT IS ALIASED WITH EFFECT AB.
CD
    ABE
WHICH EFFECT/INTERACTION DO YOU WANT TO SEE?
ENTER THE EFFECT DESCRIPTION.  ENTER A BLANK TO EXIT.
EXAMPLE:  ENTER AB TO SEE WHAT IS ALIASED WITH EFFECT AB.
```

BASIC EXPERIMENTAL BLOCK/OBSERVATION VECTOR

THESE ARE THE EXPERIMENTAL OBSERVATIONS TO BE RUN

IN THE DATA COLLECTION PROCESS.

FOR A 2 LEVEL PER FACTOR EXPERIMENT, 0 AND 1 REPRESENT THE LOW AND HIGH FACTOR VALUES. FOR A 3 LEVEL PER FACTOR EXPERIMENT, 0, 1, AND 2 REPRESENT THE LOW, INTERMEDIATE, AND HIGH FACTOR VALUES.

HIT RETURN WHEN READY TO CONTINUE.

ACTUAL EXPERIMENTAL DESIGN DEMONSTRATION

****

BASIC EXPERIMENTAL BLOCK/OBSERVATION VECTORS

ABCDE
00000
00011
00101
00110
01001
01010
01100
01111
10001
10010
10100
10111
11000
11011
11101
11110

HIT RETURN WHEN READY TO CONTINUE.

ACTUAL EXPERIMENTAL DESIGN DEMONSTRATION

****

DATA ANALYSIS

Once the data have been collected, they must be analyzed to identify significant effects. This analysis could consist of an analysis of variance (ANOVA) or of a regression analysis.

The capability to perform the data analysis has not been included in this program at this time since a program to analyze a fractional factorial experiment with both regression analysis and ANOVA techniques would be a full-time project in itself. The program user should analyze his data with existing routines available at AMRL.

EXPERIMENTAL REFINEMENT

Once the experiment has conducted a fraction of a total factorial experiment, an analysis of this basic block may provide sufficient data to preclude additional data collection. If one or more factors produce significant results, all further work may be confined to studying these factors in detail. The experiment may be redesigned with fewer factors or with other factors added. Additional work is required if:

1. The main effects are not given with sufficient precision.
2. Some main effects may be confused with two-factor interactions and may require separation.
3. Some two-factor interactions may require separation.
4. Additional factors may need to be included in the design.

Separation of Aliases

Separation of aliases assumes that a fractional design has been executed and that we wish to carry out a second fraction in order to obtain a higher degree of precision and/or to separate the main effects from two-factor interactions.

A 1/2 factorial or a 1/3 factorial will require a full factorial to separate aliases. Thus, this assumes that a 1/4 or 1/9 (etc.) replicate has been performed and the problem is to separate effect X from effect Y, i.e., X and Y are in the same aliasing group, X = Y.

The user will define the aliased terms and the program will tell the user which of his original alias terms may be deleted to remove this aliasing.

The following is an example of the separation of alias feature.

The problem can be defined in one of two ways. The user may use program Segments 2 and 3 to define the problem, then enter Segment 5 to perform the refinement.

Or the user may enter directly into Segment 5 in which case, the program will prompt him for the program definition.

```
***************************************************************************
WELCOME TO THE SCREENING DESIGNS PROGRAM.
YOU MAY ENTER ONE OF THE PROGRAM SEGMENTS:
     1.  BASIC TERMINOLOGY
     2.  PROBLEM DEFINITION
     3.  ACTUAL EXPERIMENTAL DESIGN
     4.  DATA ANALYSIS
     5.  EXPERIMENTAL REFINEMENT
     6.  EXIT

ENTER THE SEGMENT NUMBER YOU WANT AND HIT RETURN
2
YOUR ENTRY WAS:  2--PROBLEM DEFINITION
PLEASE ENTER THIS RUN PROBLEM I.D.
EXPERIMENTAL REFINEMENT DEMONSTRATION
NOW WE MUST DEFINE THE SPECIFIC PROBLEM TO BE ANALYZED IN THIS RUN.
HOW MANY LEVELS FOR THE FACTORS?
2
HOW MANY FACTORS ARE INVOLVED?
6
HOW MANY EXPERIMENTAL TRIALS ARE AVAILABLE?
20
  2 LEVELS FOR THE FACTORS.  IS THIS CORRECT?
Y
  6 FACTORS ARE PRESENT.  IS THIS CORRECT?
Y
 20 TRIALS ARE AVAILABLE.  IS THIS CORRECT?
Y
      63 IS THE TOTAL NUMBER OF EFFECTS AND INTERACTIONS.
            OF THESE:
       6 ARE MAIN EFFECTS
      15 ARE FIRST ORDER INTERACTIONS.
      42 ARE HIGHER ORDER INTERACTIONS.
HIT RETURN WHEN READY TO CONTINUE
```

This is an example of using Segments 2 and 3 to define the problem.

```
EXPERIMENTAL REFINEMENT DEMONSTRATION
**********************************************************************************
HOW MANY EXPERIMENTAL TRIALS ARE TO BE RUN?
THIS MUST BE SELECTED FROM THE VALUES:
       2      4      8      16      32      64
16
IS THIS WHAT YOU WANT:  16
Y

FOR AN EXPERIMENT OF THIS SIZE, YOU WILL NEED 2 LINEARLY INDEPENDENT ALIAS(ES)

THE FACTORS IN THE DESIGN MUST BE DESIGNATED AS A,B,C,D, ETC.
THE LETTER I IS RESERVED FOR THE IDENTITY EFFECT.

SINCE EACH FACTOR MUST APPEAR IN A TREATMENT, THE FOLLOWING NOTATION IS USED TO DESCRIBE
THE FACTORS IN A PARTICULAR TRIAL OR ALIAS DEFINITION.
FOR A 2 LEVEL PER FACTOR EXPERIMENT, THE ABSENCE OF A LETTER INDICATES THE FACTOR IS AT
ITS LOW LEVEL.
THE PRESENCE OF A LETTER INDICATES THE FACTOR IS AT ITS HIGH LEVEL.

FOR A 3 LEVEL PER FACTOR EXPERIMENT, THE ABSENCE OF A LETTER IS THE LOW LEVEL, THE
PRESENCE OF THE LETTER INDICATES THE INTERMEDIATE LEVEL, WHILE THE LETTER FOLLOWED
BY A 2 INDICATES THE HIGH LEVEL.

FOR 2 LEVEL PER FACTOR: AC MEANS FACTOR A AT ITS HIGH LEVEL, FACTOR B AT ITS LOW LEVEL,
AND FACTOR C AT ITS HIGH LEVEL.

FOR 3 LEVELS PER FACTOR: A2C MEANS FACTOR A AT ITS HIGH LEVEL, FACTOR B AT ITS LOW LEVEL,
AND FACTOR C AT ITS INTERMEDIATE LEVEL.
DO YOU WANT SOME HELP WITH THE ALIAS DEFINITION?
NO
```

```
REMEMBER THAT THE ALIAS MUST BE OF THE FORM EFFECT 1 = EFFECT 2
THE FIRST ALIAS EFFECT IS INPUT THEN THE SECOND.

ALIAS NO. 1 FIRST TERM
I
ALIAS NO. 1 SECOND TERM
ABCD
IS THIS CORRECT?
I                  =ABCD
Y
ALIAS NO. 2 FIRST TERM
I
ALIAS NO. 2 SECOND TERM
ACDEF
IS THIS CORRECT?
I                  =ACDEF
Y
THE ALIAS SET DEFINED CONTAINS 2 INDEPENDENT MEMBERS.

DO YOU WANT TO SEE THE TOTAL ALIAS SET?
YES
                   TOTAL ALIAS SET
                   BEF
                   ACDEF
                   ABCD
HIT RETURN WHEN READY TO CONTINUE.

WOULD YOU LIKE TO REDEFINE THE ALIASES?
NO
PROBLEM DEFINITION COMPLETED.
HIT RETURN WHEN READY TO CONTINUE.
```

```
*************************************************************************
WELCOME TO THE SCREENING DESIGNS PROGRAM.
YOU MAY ENTER ONE OF THE PROGRAM SEGMENTS:

     1.  BASIC TERMINOLOGY
     2.  PROBLEM DEFINITION
     3.  ACTUAL EXPERIMENTAL DESIGN
     4.  DATA ANALYSIS
     5.  EXPERIMENTAL REFINEMENT
     6.  EXIT

ENTER THE SEGMENT NUMBER YOU WANT AND HIT RETURN
3
YOUR ENTRY WAS:  3--ACTUAL EXPERIMENTAL DESIGN

PLEASE ENTER THIS RUN PROBLEM I.D.
EXPERIMENTAL REFINEMENT DEMONSTRATION
```

THIS IS A SUMMARY OF THE NUMBER OF MAIN EFFECTS AND FIRST ORDER INTERACTIONS CONFOUNDED WITH EACH MAIN EFFECT AND FIRST ORDER INTERACTION.
MAIN EFFECTS ARE MARKED WITH THE LETTER M, AND THOSE MAIN EFFECTS THAT ARE CONFOUNDED WITH OTHER MAIN EFFECTS ARE FLAGGED WITH AN *.

HIT RETURN WHEN READY TO CONTINUE.

EXPERIMENTAL DESIGN SUMMARY

MAIN	1-ST	HIGHER		EFFECT
0	0	3	M	A
0	1	2		AB
0	1	2		AC
0	1	2		AD
0	0	3		AE
0	0	3		AF
0	1	2	M	B
0	1	2		BC
0	1	2		BD
1	0	2		BE
1	0	2		BF
0	0	3	M	C
0	1	2		CD
0	0	3		CE
0	0	3		CF
0	0	3	M	D
0	0	3		DE
0	0	3		DF
0	1	2	M	E

HIT RETURN WHEN READY TO CONTINUE

1	0	2		EF
0	1	2	M	F

END OF SUMMARY TABLE

HIT RETURN WHEN READY TO CONTINUE

```
EXPERIMENTAL REFINEMENT DEMONSTRATION
******************************************************************************

WHICH EFFECT/INTERACTION DO YOU WANT TO SEE?
ENTER THE EFFECT DESCRIPTION.  ENTER A BLANK TO EXIT.
EXAMPLE:  ENTER AB TO SEE WHAT IS ALIASED WITH EFFECT AB.
A

     ABEF
     CDEF
     BCD
WHICH EFFECT/INTERACTION DO YOU WANT TO SEE?
ENTER THE EFFECT DESCRIPTION.  ENTER A BLANK TO EXIT.
EXAMPLE:  ENTER AB TO SEE WHAT IS ALIASED WITH EFFECT AB.
BASIC EXPERIMENTAL BLOCK/OBSERVATION VECTOR
THESE ARE THE EXPERIMENTAL OBSERVATIONS TO BE RUN IN THE DATA COLLECTION PROCESS.
FOR A 2 LEVEL PER FACTOR EXPERIMENT, 0 AND 1 REPRESENT THE LOW AND HIGH FACTOR
VALUES.  FOR A 3 LEVEL PER FACTOR EXPERIMENT, 0, 1, AND 2 REPRESENT THE LOW,
INTERMEDIATE, AND HIGH FACTOR VALUES.
HIT RETURN WHEN READY TO CONTINUE.

EXPERIMENTAL REFINEMENT DEMONSTRATION
*****************************************************************************
BASIC EXPERIMENTAL BLOCK/OBSERVATION VECTORS

     ABCDEF
     000000
     000011
     001100
     001111
     010101
     010110
     011001
     011010
     100100
     100111
     101000
     101011
     110001
     110010
     111101
     111110

HIT RETURN WHEN READY TO CONTINUE.
EXPERIMENTAL REFINEMENT DEMONSTRATION
****************************************************************************
```

Note that effect A is confounded with effect ABEF. The user may want to use Segment 5 to separate these two effects.

```
*********************************************************************
WELCOME TO THE SCREENING DESIGNS PROGRAM.
YOU MAY ENTER ONE OF THE PROGRAM SEGMENTS.

     1.  BASIC TERMINOLOGY
     2.  PROBLEM DEFINITION
     3.  ACTUAL EXPERIMENTAL DESIGN
     4.  DATA ANALYSIS
     5.  EXPERIMENTAL REFINEMENT
     6.  EXIT

ENTER THE SEGMENT NUMBER YOU WANT AND HIT RETURN
5

YOUR ENTRY WAS:  5--EXPERIMENTAL REFINEMENT

PLEASE ENTER THIS RUN PROBLEM I.D.
EXPERIMENTAL REFINEMENT DEMONSTRATION
```

EXPERIMENTAL REFINEMENT DEMONSTRATION
****

I HAVE THE BASIC EXPERIMENTAL BLOCK AS IN THE ORIGINAL PROBLEM.
NOW, YOU MUST SPECIFY THE TWO ALIASED EFFECTS YOU WISH TO HAVE
SEPARATED.

WHAT IS THE FIRST EFFECT:
A
WHAT IS THE SECOND EFFECT:
ABEF

ALIASED EFFECT: A

ALIASED EFFECT: ABEF
ARE THESE THE ALIASED EFFECTS?
YES

HIT RETURN WHEN READY TO CONTINUE

MAY DELETE ALIAS NUMBER 1: I=ABCD
MAY DELETE ALIAS NUMBER 2: I=ACDEF
WHICH ALIAS NUMBER WOULD YOU LIKE TO ELIMINATE?
2

The separation can be accomplished by deleting either alias number 1 or number 2. In this case, number 2 is chosen.

THIS IS A SUMMARY OF THE NUMBER OF MAIN EFFECTS AND FIRST ORDER INTERACTIONS CONFOUNDED WITH EACH MAIN EFFECT AND FIRST ORDER INTERACTION.
MAIN EFFECTS ARE MARKED WITH THE LETTER M, AND THOSE MAIN EFFECTS THAT ARE CONFOUNDED WITH OTHER MAIN EFFECTS ARE FLAGGED WITH AN *.

HIT RETURN WHEN READY TO CONTINUE.

EXPERIMENTAL DESIGN SUMMARY

MAIN	1-ST	HIGHER		EFFECT
0	0	1	M	A
0	1	0		AB
0	1	0		AC
0	1	0		AD
0	0	1		AE
0	0	1		AF
0	0	1	M	B
0	1	0		BC
0	1	0		BD
0	0	[illegible]		BE
0	0	1		BF
0	0	1	M	C
0	1	0		CD
0	0	1		CE
0	0	1		CF
0	0	1	M	D
0	0	1		DE
0	0	1		DF
0	0	1	M	E

HIT RETURN WHEN READY TO CONTINUE

0	0	1		EF
0	0	1	M	F

END OF SUMMARY TABLE

HIT RETURN WHEN READY TO CONTINUE

```
EXPERIMENTAL REFINEMENT DEMONSTRATION
**************************************************************************
WHICH EFFECT/INTERACTION DO YOU WANT TO SEE?
ENTER THE EFFECT DESCRIPTION.  ENTER A BLANK TO EXIT.
EXAMPLE:  ENTER AB TO SEE WHAT IS ALIASED WITH EFFECT AB.
A

     BCD
WHICH EFFECT/INTERACTION DO YOU WANT TO SEE?
ENTER THE EFFECT DESCRIPTION.  ENTER A BLANK TO EXIT.
EXAMPLE:  ENTER AB TO SEE WHAT IS ALIASED WITH EFFECT AB.
```

NOTE: Effect A is no longer confounded with ABEF.

BASIC EXPERIMENTAL BLOCK/OBSERVATION VECTOR

THESE ARE THE EXPERIMENTAL OBSERVATIONS TO BE RUN IN THE DATA COLLECTION PROCESS.

FOR A 2 LEVEL PER FACTOR EXPERIMENT, 0 AND 1 REPRESENT THE LOW AND HIGH FACTOR VALUES. FOR A 3 LEVEL PER FACTOR EXPERIMENT, 0 , 1, AND 2 REPRESENT THE LOW, INTERMEDIATE, AND HIGH FACTOR VALUES.

NEW TRIALS (NOT PART OF PREVIOUS BLOCK) ARE MARKED WITH THE LETTER N.

HIT RETURN WHEN READY TO CONTINUE.

EXPERIMENTAL REFINEMENT DEMONSTRATION

```
************************************************************************
BASIC EXPERIMENTAL BLOCK/OBSERVATION VECTORS

        ABCDEF
        000000
    N   000001
    N   000010
        000011
        001100
    N   001101
    N   001110
        001111
    N   010100
        010101
        010110
    N   010111
    N   011000
        011001
        011010
    N   011011
        100100
    N   100101
    N   100110
        100111

HIT RETURN WHEN READY TO CONTINUE.

        ABCDEF
        101000
    N   101001
    N   101010
        101011
    N   110000
        110001
        110010
    N   110011
    N   111100
        111101
        111110
    N   111111

HIT RETURN WHEN READY TO CONTINUE
```

Assuming that the previous block of experiments had already been performed, only those trials marked with an N (new) need be run now.

```
**********************************************************************
WELCOME TO THE SCREENING DESIGNS PROGRAM.
YOU MAY ENTER ONE OF THE PROGRAM SEGMENTS:

     1.  BASIC TERMINOLOGY
     2.  PROBLEM DEFINITION
     3.  ACTUAL EXPERIMENTAL DESIGN
     4.  DATA ANALYSIS
     5.  EXPERIMENTAL REFINEMENT
     6.  EXIT

ENTER THE SEGMENT NUMBER YOU WANT AND HIT RETURN
5
YOUR ENTRY WAS:  5--EXPERIMENTAL REFINEMENT
PLEASE ENTER THIS RUN PROBLEM I.D.
EXPERIMENTAL REFINEMENT DEMONSTRATION
```

This is an example of entering directly into Segment number 5, without first entering Segment 2.

```
EXPERIMENTAL REFINEMENT DEMONSTRATION
**********************************************************************
THIS REQUIRES THAT THE EXPERIMENTER DESCRIBE THE ORIGINAL DESIGN.
THE MOST EFFICIENT WAY TO DESCRIBE THE ORIGINAL DESIGN IS TO USE THE PROGRAM
DESIGN DEFINITION CAPABILITY AS IN SEGMENTS 2 AND 3.

YOU MUST SPECIFY THE DESIGN IN THE SAME WAY AS IN THE ORIGINAL RUN.
NOW WE MUST DEFINE THE SPECIFIC PROBLEM TO BE ANALYZED IN THIS RUN.
HOW MANY LEVELS FOR THE FACTORS?
2
HOW MANY FACTORS ARE INVOLVED?
6
HOW MANY EXPERIMENTAL TRIALS ARE AVAILABLE?
16
  2 LEVELS FOR THE FACTORS.  IS THIS CORRECT?
YES
  6 FACTORS ARE PRESENT.  IS THIS CORRECT?
Y
  16 TRIALS ARE AVAILABLE.  IS THIS CORRECT?
Y
      63 IS THE TOTAL NUMBER OF EFFECTS AND INTERACTIONS.
 OF THESE:
       6 ARE MAIN EFFECTS.
      15 ARE FIRST ORDER INTERACTIONS.
      42 ARE HIGHER ORDER INTERACTIONS.

HIT RETURN WHEN READY TO CONTINUE

EXPERIMENTAL REFINEMENT DEMONSTRATION
*******************************************************************
HOW MANY EXPERIMENTAL TRIALS ARE TO BE RUN?
THIS MUST BE SELECTED FROM THE VALUES:
     2       4       8       16       32       64
16
IS THIS WHAT YOU WANT:   16
Y
```

```
FOR AN EXPERIMENT OF THIS SIZE, YOU WILL NEED 2 LINEARLY INDEPENDENT ALIAS(ES)

THE FACTORS IN THE DESIGN MUST BE DESIGNATED AS A,B,C,D, ETC.
THE LETTER I IS RESERVED FOR THE IDENTITY EFFECT.

SINCE EACH FACTOR MUST APPEAR IN A TREATMENT, THE FOLLOWING NOTATION IS USED TO DESCRIBE
THE FACTORS IN A PARTICULAR TRIAL OR ALIAS DEFINITION.
FOR A 2 LEVEL PER FACTOR EXPERIMENT, THE ABSENCE OF A LETTER INDICATES THE FACTOR IS AT
ITS LOW LEVEL.
THE PRESENCE OF A LETTER INDICATES THE FACTOR IS AT ITS HIGH LEVEL.

FOR A 3 LEVEL PER FACTOR EXPERIMENT, THE ABSENCE OF A LETTER IS THE LOW LEVEL.  THE
PRESENCE OF THE LETTER INDICATES THE INTERMEDIATE LEVEL, WHILE THE LETTER FOLLOWED BY
A 2 INDICATES THE HIGH LEVEL.

FOR 2 LEVEL PER FACTOR: AC MEANS FACTOR A AT ITS HIGH LEVEL, FACTOR B AT ITS LOW LEVEL,
AND FACTOR C AT ITS HIGH LEVEL.

FOR 3 LEVELS PER FACTOR: A2C MEANS FACTOR A AT ITS HIGH LEVEL, FACTOR B AT ITS LOW LEVEL,
AND FACTOR C AT ITS INTERMEDIATE LEVEL.
DO YOU WANT SOME HELP WITH THE ALIAS DEFINITION?
NO
```

```
REMEMBER THAT THE ALIAS MUST BE OF THE FORM EFFECT 1 = EFFECT 2
THE FIRST ALIAS EFFECT IS INPUT THEN THE SECOND.

ALIAS NO. 1 FIRST TERM
I
ALIAS NO. 1 SECOND TERM
ABCD
IS THIS CORRECT?
I                     =ABCD
YES
ALIAS NO. 2 FIRST TERM
I
ALIAS NO. 2 SECOND TERM
ACDEF
IS THIS CORRECT?
I                     =ACDEF
Y
THE ALIAS SET DEFINED CONTAINS 2 INDEPENDENT MEMBERS.

DO YOU WANT TO SEE THE TOTAL ALIAS SET?
NO
WOULD YOU LIKE TO REDEFINE THE ALIASES?

I DID NOT UNDERSTAND YOUR RESPONSE.
PLEASE ANSWER THE QUESTION WITH A YES OR NO RESPONSE
NO
```

EXPERIMENTAL REFINEMENT DEMONSTRATION

****

THIS IS A SUMMARY OF THE NUMBER OF MAIN EFFECTS AND FIRST ORDER INTERACTIONS CONFOUNDED WITH EACH MAIN EFFECT AND FIRST ORDER INTERACTION.

MAIN EFFECTS ARE MARKED WITH THE LETTER M, AND THOSE MAIN EFFECTS THAT ARE CONFOUNDED WITH OTHER MAIN EFFECTS ARE FLAGGED WITH AN *.

HIT RETURN WHEN READY TO CONTINUE.

EXPERIMENTAL DESIGN SUMMARY

MAIN	1-ST	HIGHER		EFFECT
0	0	3	M	A
0	1	2		AB
0	1	2		AC
0	1	2		AD
0	0	3		AE
0	0	3		AF
0	1	2	M	B
0	1	2		BC
0	1	2		BD
1	0	2		BE
1	0	2		BF
0	0	3	M	C
0	1	2		CD
0	0	3		CE
0	0	3		CF
0	0	3	M	D
0	0	3		DE
0	0	3		DF
0	1	2	M	E

HIT RETURN WHEN READY TO CONTINUE

1	0	2		EF
0	1	2	M	F

END OF SUMMARY TABLE

HIT RETURN WHEN READY TO CONTINUE.

EXPERIMENTAL REFINEMENT DEMONSTRATION
****

```
WHICH EFFECT/INTERACTION DO YOU WANT TO SEE?
ENTER THE EFFECT DESCRIPTION.  ENTER A BLANK TO EXIT.
EXAMPLE:  ENTER AB TO SEE WHAT IS ALIASED WITH EFFECT AB.
A
      ABEF
      CDEF
      BCD
WHICH EFFECT/INTERACTION DO YOU WANT TO SEE?
ENTER THE EFFECT DESCRIPTION.  ENTER A BLANK TO EXIT.
EXAMPLE:  ENTER AB TO SEE WHAT IS ALIASED WITH EFFECT AB.
```

BASIC EXPERIMENTAL BLOCK/OBSERVATION VECTOR

THESE ARE THE EXPERIMENTAL OBSERVATIONS TO BE RUN IN THE DATA COLLECTION PROCESS.

FOR A 2 LEVEL PER FACTOR EXPERIMENT, 0 AND 1 REPRESENT THE LOW AND HIGH FACTOR VALUES. FOR A 3 LEVEL PER FACTOR EXPERIMENT, 0,1, AND 2 REPRESENT THE LOW, INTERMEDIATE, AND HIGH FACTOR VALUES.

HIT RETURN WHEN READY TO CONTINUE.

EXPERIMENTAL REFINEMENT DEMONSTRATION

****

BASIC EXPERIMENTAL BLOCK/OBSERVATION VECTORS

```
ABCDEF
000000
000011
001100
001111
010101
010110
011001
011010
100100
100111
101000
101011
110001
110010
111101
111110
```

HIT RETURN WHEN READY TO CONTINUE.

EXPERIMENTAL REFINEMENT DEMONSTRATION

****

```
EXPERIMENTAL REFINEMENT DEMONSTRATION
**********************************************************************
I HAVE THE BASIC EXPERIMENTAL BLOCK AS IN THE ORIGINAL PROBLEM.
NOW, YOU MUST SPECIFY THE TWO ALIASED EFFECTS YOU WISH TO HAVE SEPARATED.

WHAT IS THE FIRST EFFECT:
A
WHAT IS THE SECOND EFFECT:
ABEF

ALIASED EFFECT:  A
ALIASED EFFECT:  ABEF
ARE THESE THE ALIASED EFFECTS?
YES

HIT RETURN WHEN READY TO CONTINUE

MAY DELETE ALIAS NUMBER 1:  I=ABCD
MAY DELETE ALIAS NUMBER 2:  I=ACDEF
WHICH ALIAS NUMBER WOULD YOU LIKE TO ELIMINATE?
2
```

THIS IS A SUMMARY OF THE NUMBER OF MAIN EFFECTS AND FIRST ORDER INTERACTIONS CONFOUNDED WITH EACH MAIN EFFECT AND FIRST ORDER INTERACTION. MAIN EFFECTS ARE MARKED WITH THE LETTER M, AND THOSE MAIN EFFECTS THAT ARE CONFOUNDED WITH OTHER MAIN EFFECTS ARE FLAGGED WITH AN *.

HIT RETURN WHEN READY TO CONTINUE.

EXPERIMENTAL DESIGN SUMMARY

MAIN	1-ST	HIGHER		EFFECT
0	0	1	M	A
0	1	0		AB
0	1	0		AC
0	1	0		AD
0	0	1		AE
0	0	1		AF
0	0	1	M	B
0	1	0		BC
0	1	0		BD
0	0	1		BE
0	0	1		BF
0	0	1	M	C
0	1	0		CD
0	0	1		CE
0	0	1		CF
0	0	1	M	D
0	0	1		DE
0	0	1		DF
0	0	1	M	E

HIT RETURN WHEN READY TO CONTINUE

0	0	1		EF
0	0	1	M	F

END OF SUMMARY TABLE

HIT RETURN WHEN READY TO CONTINUE

EXPERIMENTAL REFINEMENT DEMONSTRATION

```
**********************************************************************
WHICH EFFECT/INTERACTION DO YOU WANT TO SEE?
ENTER THE EFFECT DESCRIPTION.  ENTER A BLANK TO EXIT.
EXAMPLE:  ENTER AB TO SEE WHAT IS ALIASED WITH EFFECT AB.
A
     BCD
WHICH EFFECT/INTERACTION DO YOU WANT TO SEE?
ENTER THE EFFECT DESCRIPTION.  ENTER A BLANK TO EXIT.
EXAMPLE:  ENTER AB TO SEE WHAT IS ALIASED WITH EFFECT AB.
```

BASIC EXPERIMENTAL BLOCK/OBSERVATION VECTOR

THESE ARE THE EXPERIMENTAL OBSERVATIONS TO BE RUN IN THE DATA COLLECTION PROCESS.

FOR A 2 LEVEL PER FACTOR EXPERIMENT, 0 AND 1 REPRESENT THE LOW AND HIGH FACTOR VALUES. FOR A 3 LEVEL PER FACTOR EXPERIMENT, 0,1, AND 2 REPRESENT THE LOW, INTERMEDIATE, AND HIGH FACTOR VALUES.

NEW TRIALS (NOT PART OF PREVIOUS BLOCK) ARE MARKED WITH THE LETTER N.

HIT RETURN WHEN READY TO CONTINUE.

EXPERIMENTAL REFINEMENT DEMONSTRATION

```
************************************************************************
BASIC EXPERIMENTAL BLOCK/OBSERVATION VECTORS

        ABCDEF
        000000
   N    000001
   N    000010
        000011
        001100
   N    001101
   N    001110
        001111
   N    010100
        010101
        010110
   N    010111
   N    011000
        011001
        011010
   N    011011
        100100
   N    100101
   N    100110
        100111
HIT RETURN WHEN READY TO CONTINUE.
        ABCDEF
        101000
   N    101001
   N    101010
        101011
   N    110000
        110001
        110010
   N    110011
   N    111100
        111101
        111110
   N    111111

HIT RETURN WHEN READY TO CONTINUE.
```

EXIT

Segment 6--Exit is the segment to enter to exit from the Sequential Design Program.

The following is an example of its use.

```
**********************************************************************
WELCOME TO THE SCREENING DESIGNS PROGRAM.
YOU MAY ENTER ONE OF THE PROGRAM SEGMENTS:

     1.  BASIC TERMINOLOGY
     2.  PROBLEM DEFINITION
     3.  ACTUAL EXPERIMENTAL DESIGN
     4.  DATA ANALYSIS
     5.  EXPERIMENTAL REFINEMENT
     6.  EXIT

ENTER THE SEGMENT NUMBER YOU WANT AND HIT RETURN
6
YOUR ENTRY WAS: 6--EXIT PROGRAM

PLEASE ENTER THIS RUN I.D. STRING
EXIT TEST
ROUTINE WRAP-UP ENTERED--
NO INTERNAL PROCESSING REQUIRED BY THIS SYSTEM.
FORTRAN STOP
```

MISVAL EXPERIMENTAL DESIGN

In the MISVAL program, MIL (Man-In-The-Loop) experiments, as described previously, the total set of factors considered in the design problem can be described and summarized as shown in Table 1. In this problem, there are three factors at two levels and eight factors at three levels for a $2^3 \times 3^8$ mixed factorial experiment. The specific definitions of factors and levels in the MISVAL example are not considered necessary in order to convey the intent of the example. However, most are self-explanatory. Also, note that several factors are qualitative. These factors would have to be appropriately scaled or used in a nested design in an actual experimental program. A full factorial experiment would require 52488 experimental units in a single replication. This is obviously unrealistic because of time and budget considerations. A full factorial experiment would permit the experimenter to determine the significance of each interaction, i.e., main effects, first-order, and higher-order interactions. With the assumption that only main effects and first-order interactions are significant, a fractional factorial experiment can be conducted to evaluate all main effects and first-order interactions.

This problem is further complicated because of some of the factors have two levels whereas the remaining factors have three levels. This leads to a mixed factorial design. Fortunately, a mixed factorial can be represented as the cartesian product of two independent experimental designs. Hence, a fractional factorial design for three factors at two levels must be "crossed" with a fractional factorial design for eight factors at three levels.

For a 2^3 factorial design, a 1/2 replicate using the aliasing I=ABC will produce the fractional design, I, AB, BC, and AC as the entries in the observation vector. The aliasing in this case leads to (A,BC), (B,AC), (C,AB) which will permit the identification of significant main effects. However, since each main effect is aliased with a first-order interaction, it will be impossible to decide if a significant effect, A for example, is attributable to A or to the interaction BC. A follow-on experiment to separate A and BC would have to be performed. This separation experiment will eventually lead to a full factorial experiment for the 2^3 portion of the design. However, for now, the assumption that first-order interactions are insignificant will be made.

For the 3^8 factorial design, a 1/81 replicate using the aliasing $I=ACDEF^2G=BC^2EF^2G=ABCEG^2=AB^2CD^2E^2F^2G^2H^2$ will produce the fractional design shown in the program implementation following.

This aliasing permits the evaluation of all main effects and some of the first-order interactions in only 81 observations.

By crossing these two fractional designs, there will be a total of 4*81=324 experimental units in the initial observation vector. Replicating this design three times to allow for pilot variation would require 972 experimental units. This would account for approximately 30 percent of the experimental budget. At this time, an analysis of the data would be performed and all insignificant factors could be removed from the design.

For example, if target speed, target altitude, launcher speed, and launcher altitude are found to be insignificant, the problem then becomes a $2^3 \times 3^4$ mixed factorial experiment. A full factorial experiment would require 648 experimental units. The 972 units run previously would form a significant portion of these 648 units needed for a full factorial experiment when replication of combinations is considered.

Three replications of the full $2^3 \times 3^4$ factorial experiment with the 972 units already run would require less than 3000 experimental units. This is within the experimental budget.

Table 1. MISVAL Factors

Factor	Value
Concept/Algorithm	1. FAAC algorithm
	2. GD algorithm
Missile Type	1. AIM-7F
	2. AIM-9L
Pilot Steering Function	1. Missile Launch Opportunity Selection
	2. Steering Functions
Target Altitude	1. .5 KFT
	2. 20 KFT
	3. 40 KFT
Launch Altitude	1. .5 KFT
	2. 20 KFT
	3. 40 KFT
Target Speed	1. .7 MACH
	2. .9 MACH
	3. 1.1 MACH
Launch Speed	1. .7 MACH
	2. .9 MACH
	3. 1.1 MACH

Table 1. MISVAL Factors (Continued)

Aspect Angles	1.	Nose
	2.	Tail
	3.	Beam
Heading Angles	1.	Collision Course
	2.	+20 Degrees
	3.	-20 Degrees
Turn	1.	No Turn
	2.	Max G Turn 1
	3.	Max G Turn 2
Evasion	1.	Dive
	2.	Climb
	3.	No Evasion

AD-A115 518 SYSTEM DEVELOPMENT CORP DAYTON OHIO F/G 9/2
THE USER-ASSISTED AUTOMATED EXPERIMENTAL (TEST), DESIGN PROGRAM--ETC(U)
FEB 82 E G MEYER, C M HOYLAND, R G MILLS F33615-79-C-0505

UNCLASSIFIED AFAMRL-TR-81-100 NL

2 OF 2

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The following material shows the use of this program to design the experimental procedure required in the MISVAL program. This process consists of two parts. The first is a design of a 1/2 fractional factorial of a 2^3 experiment, and the second is a 1/81 fractional factorial of a 3^8 experiment.

```
**********************************************************************
WELCOME TO THE SCREENING DESIGNS PROGRAM.
YOU MAY ENTER ONE OF THE PROGRAM SEGMENTS:

     1.  BASIC TERMINOLOGY
     2.  PROBLEM DEFINITION
     3.  ACTUAL EXPERIMENTAL DESIGN
     4.  DATA ANALYSIS
     5.  EXPERIMENTAL REFINEMENT
     6.  EXIT

ENTER THE SEGMENT NUMBER YOU WANT AND HIT RETURN
2
YOUR ENTRY WAS:  2--PROBLEM DEFINITION

PLEASE ENTER THIS RUN PROBLEM I.D.
MISVAL DEMONSTRATION

NOW WE MUST DEFINE THE SPECIFIC PROBLEM  TO BE ANALYZED IN THIS RUN.

HOW MANY LEVELS FOR THE FACTORS?
2
HOW MANY FACTORS ARE INVOLVED?
3
HOW MANY EXPERIMENTAL TRIALS ARE AVAILABLE?
4
  2 LEVELS FOR THE FACTORS.  IS THIS CORRECT?
Y
  3 FACTORS ARE PRESENT.  IS THIS CORRECT?
Y
  4 TRIALS ARE AVAILABLE.  IS THIS CORRECT?
Y

       7 IS THE TOTAL NUMBER OF EFFECTS AND INTERACTIONS.
OF THESE:
       3 ARE MAIN EFFECTS.
       3 ARE FIRST ORDER INTERACTIONS.
       1 ARE HIGHER ORDER INTERACTIONS.
HIT RETURN WHEN READY TO CONTINUE
```

```
MISVAL DEMONSTRATION
*********************************************************************************
HOW MANY EXPERIMENTAL TRIALS ARE TO BE RUN?
THIS MUST BE SELECTED FROM THE VALUES:
     2    4    8
4
IS THIS WHAT YOU WANT:    4
Y
FOR AN EXPERIMENT OF THIS SIZE, YOU WILL NEED 1 LINEARLY INDEPENDENT ALIAS (ES)
THE FACTORS IN THE DESIGN MUST BE DESIGNATED AS A,B,C,D, ETC.
THE LETTER I IS RESERVED FOR THE IDENTITY EFFECT.
SINCE EACH FACTOR MUST APPEAR IN A TREATMENT, THE FOLLOWING NOTATION IS USED TO
DESCRIBE THE FACTORS IN A PARTICULAR TRIAL OR ALIAS DEFINITION.
FOR A 2 LEVEL PER FACTOR EXPERIMENT, THE ABSENCE OF A LETTER INDICATED THE FACTOR
IS AT ITS LOW LEVEL.  THE PRESENCE OF A LETTER INDICATES THE FACTOR IS AT ITS HIGH LEVEL.

FOR A 3 LEVEL PER FACTOR EXPERIMENT, THE ABSENCE OF A LETTER IS THE LOW LEVEL.
THE PRESENCE OF THE LETTER INDICATES THE INTERMEDIATE  LEVEL, WHILE THE LETTER
FOLLOWED BY A 2 INDICATES THE HIGH LEVEL.
FOR 2 LEVEL PER FACTOR:  AC MEANS FACTOR A AT ITS HIGH LEVEL, FACTOR B AT ITS LOW LEVEL
AND FACTOR C AT ITS HIGH LEVEL.
FOR 3 LEVELS PER FACTOR: A2C MEANS FACTOR A AT ITS HIGH LEVEL, FACTOR B AT ITS LOW LEVEL
AND FACTOR C AT ITS INTERMEDIATE LEVEL.
DO YOU WANT SOME HELP WITH THE ALIAS DEFINITION?
NO
```

REMEMBER THAT THE ALIAS MUST BE OF THE FORM EFFECT 1 = EFFECT 2

THE FIRST ALIAS EFFECT IS INPUT THEN THE SECOND.

ALIAS NO. 1 FIRST TERM

I

ALIAS NO. 1 SECOND TERM

ABC

IS THIS CORRECT?

I =ABC

Y

THE ALIAS SET DEFINED CONTAINS 1 INDEPENDENT MEMBERS.

DO YOU WANT TO SEE THE TOTAL ALIAS SET?

NO

WOULD YOU LIKE TO REDEFINE THE ALIASES?

NO

PROBLEM DEFINITION COMPLETED.

HIT RETURN WHEN READY TO CONTINUE.

```
*******************************************************************
WELCOME TO THE SCREENING DESIGNS PROGRAM.
YOU MAY ENTER ONE OF THE PROGRAM SEGMENTS:

     1.  BASIC TERMINOLOGY
     2.  PROBLEM DEFINITION
     3.  ACTUAL EXPERIMENTAL DESIGN
     4.  DATA ANALYSIS
     5.  EXPERIMENTAL REFINEMENT
     6.  EXIT

ENTER THE SEGMENT NUMBER YOU WANT AND HIT RETURN
3
YOUR ENTRY WAS:  3--ACTUAL EXPERIMENTAL DESIGN

PLEASE ENTER THIS RUN PROBLEM I.D.
MISVAL DEMONSTRATION
```

THIS IS A SUMMARY OF THE NUMBER OF MAIN EFFECTS AND FIRST ORDER INTERACTIONS CONFOUNDED WITH EACH MAIN EFFECT AND FIRST ORDER INTERACTION.
MAIN EFFECTS ARE MARKED WITH THE LETTER M, AND THOSE MAIN EFFECTS THAT ARE CONFOUNDED WITH OTHER MAIN EFFECTS ARE FLAGGED WITH AN *.

HIT RETURN WHEN READY TO CONTINUE.

EXPERIMENTAL DESIGN SUMMARY

MAIN	1-ST	HIGHER		EFFECT
0	1	0	M	A
1	0	0		AB
1	0	0		AC
0	1	0	M	B
1	0	0		BC
0	1	0	M	C

END OF SUMMARY TABLE

HIT RETURN WHEN READY TO CONTINUE

```
MISVAL DEMONSTRATION
*********************************************************************
WHICH EFFECT/INTERACTION DO YOU WANT TO SEE?
ENTER THE EFFECT DESCRIPTION.  ENTER A BLANK TO EXIT.
EXAMPLE:  ENTER AB TO SEE WHAT IS ALIASED WITH EFFECT AB.
A
     BC
WHICH EFFECT/INTERACTION DO YOU WANT TO SEE?
ENTER THE EFFECT DESCRIPTION.  ENTER A BLANK TO EXIT.
EXAMPLE:  ENTER AB TO SEE WHAT IS ALIASED WITH EFFECT AB.
B
     AC
WHICH EFFECT/INTERACTION DO YOU WANT TO SEE?
ENTER THE EFFECT DESCRIPTION.  ENTER A BLANK TO EXIT.
EXAMPLE:  ENTER AB TO SEE WHAT IS ALIASED WITH EFFECT AB.
C
     AB
WHICH EFFECT/INTERACTION DO YOU WANT TO SEE?
ENTER THE EFFECT DESCRIPTION.  ENTER A BLANK TO EXIT.
EXAMPLE:  ENTER AB TO SEE WHAT IS ALIASED WITH EFFECT AB.
```

BASIC EXPERIMENTAL BLOCK/OBSERVATION VECTOR
THESE ARE THE EXPERIMENTAL OBSERVATIONS TO BE RUN IN THE DATA COLLECTION PROCESS.
FOR A 2 LEVEL PER FACTOR EXPERIMENT, 0 AND 1 REPRESENT THE LOW AND HIGH FACTOR VALUES. FOR A 3 LEVEL PER FACTOR EXPERIMENT, 0, 1, AND 2 REPRESENT THE LOW, INTERMEDIATE, AND HIGH FACTOR VALUES.

HIT RETURN WHEN READY TO CONTINUE .

MISVAL DEMONSTRATION
****
BASIC EXPERIMENTAL BLOCK/OBSERVATION VECTORS

ABC
000
011
101
110

HIT RETURN WHEN READY TO CONTINUE

MISVAL DEMONSTRATION
****

Now, the fractional factorial of a 3^8 experiment is generated. This uses the aliasing:

1. $I = ACDEF^2G$
2. $I = BC^2EF^2G$
3. $I = ABCEG^2$
4. $I = AB^2CD^2E^2F^2G^2H^2$

```
*********************************************************************
WELCOME TO THE SCREENING DESIGNS PROGRAM.

YOU MAY ENTER ONE OF THE PROGRAM SEGMENTS:
     1.  BASIC TERMINOLOGY
     2.  PROBLEM DEFINITION
     3.  ACTUAL EXPERIMENTAL DESIGN
     4.  DATA ANALYSIS
     5.  EXPERIMENTAL REFINEMENT
     6.  EXIT
ENTER THE SEGMENT NUMBER YOU WANT AND HIT RETURN
2
YOUR ENTRY WAS:  2--PROBLEM DEFINITION

PLEASE ENTER THIS RUN PROBLEM I.D.
MISVAL DEMONSTRATION

NOW WE MUST DEFINE THE SPECIFIC PROBLEM
TO BE ANALYZED IN THIS RUN.


HOW MANY LEVELS FOR THE FACTORS?
3
HOW MANY FACTORS ARE INVOLVED?
8
HOW MANY EXPERIMENTAL TRIALS ARE AVAILABLE?
100
   3 LEVELS FOR THE FACTORS.  IS THIS CORRECT?
Y
   8 FACTORS ARE PRESENT.  IS THIS CORRECT?
Y
   100 TRIALS ARE AVAILABLE.  IS THIS CORRECT?
Y
    6560 IS THE TOTAL NUMBER OF EFFECTS AND INTERACTIONS.
OF THESE:
     16 ARE MAIN EFFECTS .
    112 ARE FIRST ORDER INTERACTIONS.
   6432 ARE HIGHER ORDER INTERACTIONS.

HIT RETURN WHEN READY TO CONTINUE.
```

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MISVAL DEMONSTRATION
****************************************************************************
HOW MANY EXPERIMENTAL TRIALS ARE TO BE RUN?
THIS MUST BE SELECTED FROM THE VALUES:
     3     9     27     81     243     729
81
IS THIS WHAT YOU WANT:  81
Y
FOR AN EXPERIMENT OF THIS SIZE, YOU WILL NEED 4 LINEARLY INDEPENDENT ALIAS(ES)

THE FACTORS IN THE DESIGN MUST BE DESIGNATED AS A,B,C,D, ETC.
THE LETTER I IS RESERVED FOR THE IDENTITY EFFECT.
SINCE EACH FACTOR MUST APPEAR IN A TREATMENT, THE FOLLOWING NOTATION IS USED TO
DESCRIBE THE FACTORS IN A PARTICULAR TRIAL OR ALIAS DEFINITION.
FOR A 2 LEVEL PER FACTOR EXPERIMENT, THE ABSENCE OF A LETTER INDICATES THE FACTOR
IS AT ITS LOW LEVEL.  THE PRESENCE OF A LETTER INDICATES THE FACTOR IS AT ITS
HIGH LEVEL.

FOR A 3 LEVEL PER FACTOR EXPERIMENT, THE ABSENCE OF A LETTER IS THE LOW LEVEL,
THE PRESENCE OF THE LETTER INDICATES THE INTERMEDIATE LEVEL, WHILE THE LETTER
FOLLOWED BY A 2 INDICATES THE HIGH LEVEL.

FOR 2 LEVEL PER FACTOR: AC MEANS FACTOR A AT ITS HIGH LEVEL, FACTOR B AT ITS LOW
LEVEL, AND FACTOR C AT ITS HIGH LEVEL.

FOR 3 LEVELS PER FACTOR: A2C MEANS FACTOR A AT ITS HIGH LEVEL, FACTOR B AT ITS LOW LEVEL
AND FACTOR C AT ITS INTERMEDIATE LEVEL.
DO YOU WANT SOME HELP WITH THE ALIAS DEFINITION?
NO
```

```
REMEMBER THAT THE ALIAS MUST BE OF THE FORM EFFECT 1 = EFFECT 2.
THE FIRST ALIAS EFFECT IS INPUT THEN THE SECOND.
ALIAS NO. 1 FIRST TERM
I
ALIAS NO. 1 SECOND TERM
ACDEF2G
IS THIS CORRECT?
I             = ACDEF2G
Y
ALIAS NO. 2 FIRST TERM
I
ALIAS NO. 2 SECOND TERM
BC2EF2G
IS THIS CORRECT?
I             = BC2EF2G
Y
ALIAS NO. 3 FIRST TERM
I
ALIAS NO. 3 SECOND TERM
ABCEG2
IS THIS CORRECT?
I             = ABCEG2
Y
ALIAS NO. 4 FIRST TERM
I
ALIAS NO. 4 SECOND TERM
AB2CD2E2F2G2H2
IS THIS CORRECT?
I              = AB2CD2E2F2G2H2
Y
THE ALIAS SET DEFINED CONTAINS 4 INDEPENDENT MEMBERS.

DO YOU WANT TO SEE THE TOTAL ALIAS SET?
NO
WOULD YOU LIKE TO REDEFINE THE ALIASES?
NO
PROBLEM DEFINITION COMPLETED.
HIT RETURN WHEN READY TO CONTINUE.
```

```
*********************************************************************
WELCOME TO THE SCREENING DESIGNS PROGRAM
YOU MAY ENTER ONE OF THE PROGRAM SEGMENTS.

     1.  BASIC TERMINOLOGY
     2.  PROBLEM DEFINITION
     3.  ACTUAL EXPERIMENTAL DESIGN
     4.  DATA ANALYSIS
     5.  EXPERIMENTAL REFINEMENT
     6.  EXIT

ENTER THE SEGMENT NUMBER YOU WANT AND HIT RETURN
3
YOUR ENTRY WAS:  3--ACTUAL EXPERIMENTAL DESIGN
PLEASE ENTER THIS RUN PROBLEM I.D.
MISVAL DEMONSTRATION
```

This summary shows how the main effects and two-way interactions are aliased with other higher-order effects. This appears to be a good design since no main effects are aliased with any other main effect or any two-way interaction.

THIS IS A SUMMARY OF THE NUMBER OF MAIN EFFECTS AND FIRST ORDER INTERACTIONS CONFOUNDED WITH EACH MAIN EFFECT AND FIRST ORDER INTERACTION.

MAIN EFFECTS ARE MARKED WITH THE LETTER M, AND THOSE MAIN EFFECTS THAT ARE CONFOUNDED WITH OTHER MAIN EFFECTS ARE FLAGGED WITH AN *.

HIT RETURN WHEN READY TO CONTINUE

EXPERIMENTAL DESIGN SUMMARY

MAIN	1-ST	HIGHER		EFFECT
0	0	40	M	A
0	0	40		AB
0	0	40		AB2
0	0	40		AC
0	1	39		AC2
0	0	40		AD
0	1	39		AD2
0	0	40		AE
0	1	39		AE2
0	1	39		AF
0	0	40		AF2
0	2	38		AG
0	0	40		AG2
0	0	40		AH
0	0	40		AH2
0	0	40	M	A2
0	3	37		A2B
0	0	40		A2B2
0	1	39		A2C

HIT RETURN WHEN READY TO CONTINUE

0	0	40		A2C2
0	1	39		A2D
0	1	39		A2D2
0	1	39		A2E
0	0	40		A2E2
0	1	39		A2F
0	1	39		A2F2
0	1	39		A2G
0	0	40		A2G2
0	2	38		A2H
0	0	40		A2H2
0	0	40	M	B
0	1	39		BC
0	0	40		BC2
0	0	40		BD
0	2	38		BD2
0	1	39		BE
0	0	40		BE2
0	2	38		BF
0	0	40		BF2

HIT RETURN WHEN READY TO CONTINUE

0	2	38		BG
0	0	40		BG2
0	1	39		BH
0	0	40		BH2
0	0	40	M	B2
0	1	39		B2C
0	0	40		B2C2
0	0	40		B2D
0	0	40		B2D2
0	1	39		B2E
0	0	40		B2E2
0	0	40		B2F
0	0	40		B2F2
0	0	40		B2G
0	0	40		B2G2
0	1	39		B2H
0	0	40		B2H2
0	0	40	M	C
0	0	40		CD
0	3	37		CD2

HIT RETURN WHEN READY TO CONTINUE

0	1	39		CE
0	1	39		CE2
0	0	40		CF
0	1	39		CF2
0	0	40		CG
0	1	39		CG2
0	1	39		CH
0	1	39		CH2
0	0	40	M	C2
0	0	40		C2D
0	0	40		C2D2
0	0	40		C2E
0	0	40		C2E2
0	1	39		C2F
0	0	40		C2F2
0	1	39		C2G
0	0	40		C2G2
0	0	40		C2H
0	0	40		C2H2
0	0	40	M	D

HIT RETURN WHEN READY TO CONTINUE

0	0	40		DE
0	0	40		DE2
0	0	40		DF
0	1	39		DF2
0	0	40		DG
0	0	40		DG2
0	1	39		DH
0	0	40		DH2
0	0	40	M	D2
0	0	40		D2E
0	2	38		D2E2
0	1	39		D2F
0	1	39		D2F2
0	2	38		D2G
0	1	39		D2G2
0	0	40		D2H
0	1	39		D2H2
0	0	40	M	E
0	1	39		EF
0	0	40		EF2

HIT RETURN WHEN READY TO CONTINUE

0	0	40		EG
0	0	40		EG2
0	1	39		EH
0	0	40		EH2
0	0	40	M	E2
0	0	40		E2F
0	2	38		E2F2
0	2	38		E2G
0	0	40		E2G2
0	1	39		E2H
0	0	40		E2H2
0	0	40	M	F
0	2	38		FG
0	0	40		FG2
0	0	40		FH
0	0	40		FH2
0	0	40	M	F2
0	1	39		F2G
0	0	40		F2G2
0	2	38		F2H

HIT RETURN WHEN READY TO CONTINUE

0	0	40		F2H2
0	0	40	M	G
0	2	38		GH
0	0	40		GH2
0	0	40	M	G2
0	0	40		G2H
0	1	39		G2H2
0	0	40	M	H
0	0	40	M	H2

END OF SUMMARY TABLE

HIT RETURN WHEN READY TO CONTINUE

As an example, this list shows how main effect A is aliased.

```
MISVAL DEMONSTRATION
*******************************************************************
WHICH EFFECT/INTERACTION DO YOU WANT TO SEE?

ENTER THE EFFECT DESCRIPTION.  ENTER A BLANK TO EXIT.
EXAMPLE:  ENTER AB TO SEE WHAT IS ALIASED WITH EFFECT AB.

A

      AEFG2H2
      ACD2EFGH
      AC2DGH
      AC2DEF
      ABD2E2G2H
      ABCDE2G
      ABC2EF2G
      ABC2E2H2
      AB2DF2G2
      AB2DE2FH
      AB2CF2GH2
      AB2C2D2F2H
      AB2C2D2E2FGH2
      A2D2FH2
      A2D2EF2G2H
      A2CDEF2G
      A2C2EF2H2
      A2BDEH
      A2BDE2FG2

      HIT RETURN WHEN READY TO CONTINUE

      A2BCEG2
      A2BCE2FGH2
      A2BC2D2E2FH
      A2B2G2H2
      A2B2E2F2
      A2B2CD2GH
      A2B2CD2E2F2G2H2
      A2B2C2D
      DEG2
      CF2G2
      CEGH2
      C2D2F2GH2
      C2D2EH
      BE2F2G2H2
      BCD2EFG2H2
      BCD2E2F2GH
      BC2DE2F2
      B2D2FG2H
      B2CDFG
      B2CDE2G2H

      HIT RETURN WHEN READY TO CONTINUE

      B2C2FH2
```

BASIC EXPERIMENTAL BLOCK/OBSERVATION VECTOR

THESE ARE THE EXPERIMENTAL OBSERVATIONS TO BE RUN IN THE DATA COLLECTION PROCESS.
FOR A 2 LEVEL PER FACTOR EXPERIMENT, 0 AND 1 REPRESENT THE LOW AND HIGH FACTOR VALUES. FOR A 3 LEVEL PER FACTOR EXPERIMENT 0,1, AND 2 REPRESENT THE LOW, INTERMEDIATE, AND HIGH FACTOR VALUES.

HIT RETURN WHEN READY TO CONTINUE.

```
MISVAL DEMONSTRATION
****************************************************************
BASIC EXPERIMENTAL BLOCK/OBSERVATION VECTORS

         ABCDEFGH
         00000000
         00001212
         00002121
         00110012
         00111221
         00112100
         00220021
         00221200
         00222112
         01010211
         01011120
         01012002
         01120220
         01121102
         01122011
         01200202
         01201111
         01202020
         02020122
         02021001

         HIT RETURN WHEN READY TO CONTINUE
```

```
ABCDEFGH
02022210
02100101
02101010
02102222
02210110
02211022
02212201
10020110
10021022
10022201
10100122
10101001
10102210
10210101
10211010
10212222
11000021
11001200
11002112
11110000
```

HIT RETURN WHEN READY TO CONTINUE .

```
ABCDEFGH
11111212
11112121
11220012
11221221
11222100
12010202
12011111
12012020
12120211
12121120
12122002
12200220
12201102
12202011
20010220
20011102
20012011
20120202
20121111
20122020
```

HIT RETURN WHEN READY TO CONTINUE.

```
ABCDEFGH
20200211
20201120
20202002
21020101
21021010
21022222
21100110
21101022
21102201
21210122
21211001
21212210
22000012
22001221
22002100
22110021
22111200
22112112
22220000
22221212

HIT RETURN WHEN READY TO CONTINUE.

ABCDEFGH
22222121

HIT RETURN WHEN READY TO CONTINUE.


MISVAL DEMONSTRATION
*************************************************************
```

With these two experimental designs, a total design is constructed by using each of the experimental units in the 2^3 design with each of the experimental units in the 1/81 fractional factorial experiment.

It should be noted that simple crossing of the basic blocks does not result in the best design for a mixed level design. In this case it was done for the sake of simplicity in illustrating the procedure.

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